Four essays on the economics of maternity care for health policy: evidence from Peru

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Abstract

Women's health outcomes and welfare in childbirth are intrinsically related to women's choice of provider and providers' staffing and decision making. But these factors have rarely been assessed empirically for a single population. This study is an attempt to do so in a systematic way.

I use a unique and rich patient-level dataset that spans 2011 to 2015 from Lima, Peru, and use a variety of methods to address four research questions: a) conditional logit models to assess whether women trade-off continuity of care in midwife-led maternity units against structural quality in obstetrician-led maternity units; b) synthetic difference in difference methods to evaluate the policy of opening new midwife-led maternity units on use of health care and conditional logit for evaluating its effects on women's welfare; c) linear probability models with provider and obstetrician fixed effects to investigate whether the ratio of obstetricians/child deliveries on Sundays (when there are non-scheduled C-sections) affects the C-section rate upcoding by obstetricians and women's health outcomes, and d) instrumental variables methods to investigate the effect of C-sections on maternal health outcomes.

I found that women that receive their antenatal care locally are prepared to travel further afield when it comes to giving birth, suggesting that they are prepared to accept less care continuity in midwife-led maternity units and incur higher travel costs to go to maternity units with better facilities. The introduction of new midwife-led maternity units increases women's welfare, but this effect is small compared with the investment required to set up the new midwife-led maternity units. New midwife-led maternity units have the potential to improve women's health outcomes only if they are close to an obstetrician provider and there are no midwife-led maternity units nearby.

More obstetricians on duty on Sunday leads them to perform more C-sections and they justify this behaviour by up-coding comorbidities. The variation in the number of obstetricians has mixed effects on women's health outcomes improving some and worsening others. Finally, I show that C-sections are bad for women's health, especially causing haemorrhage in low C-section-risk women. (Haemorrhage is one of the main causes of maternal death in Latin American countries).

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Declaration

I declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as references. In addition, any views expressed in this work are exclusive responsibility of the author.

Chapter 1

Introduction

In this chapter I describe the research questions of this thesis, the institutional arrangements of the maternity care setting in the Peruvian public health system, the data source and the structure of the thesis.

1.1 Research questions

Women's health outcomes and welfare in childbirth are intrinsically related to their choice of provider, the provider staffing levels and decision making, and to policy-makers' interventions in this particular market. I examine these using a rich dataset for a single population. This study attempts to answer the following specific research questions.

On the demand side, increasing medicalisation in childbirth means that highly interventionist procedures, such as Caesarean sections (C-sections), are being perceived as normal (Johanson et al., 2002). This can affect women's perceptions of quality and their choice. In this context, it is argued that continuity of care in midwife-led maternity units reduce C-sections safely (McLachlan et al., 2012; Tracy et al., 2013) and improves health outcomes (Renfrew et al., 2014; Sandall et al., 2016).

For these reasons policies to promote continuity of care in midwife-led maternity units have been recommended to improve maternal health outcomes (Betrán et al., 2018; Lancet, 2018; Wiklund et al., 2018). In this context, Chapter 2 aims to answer the following research question:

- In choosing antenatal and delivery providers how do women trade-off continuity of care, distance, and structural quality?

Women choose between continuity and shorter travel distances when receiving antenatal and delivery care in midwife-led units versus receiving antenatal care in midwife-led units and delivery in better equipped obstetrician-led units located further away. They can trade-off continuity and low travel costs against high quality delivery care.

I provide new evidence that women trade-off midwife-led continuity of care for the prospect of better structural quality at delivery in better equipped obstetrician-led providers, where women are willing to travel longer distances to give birth.

I use a conditional logit model to assess the extent to which women trade-off continuity of care in midwife-led maternity units against structural quality in obstetrician-led maternity units. My findings in Chapter 2 suggest that greater availability of less well-equipped midwife-led maternity facilities does not guarantee their use for child delivery, even if they are closer and even if prospective mothers received their antenatal care there. Women are willing to travel further and sacrifice continuity of care in midwife-led maternity units in order to deliver in better equipped providers.

In Lima most specialised facilities offer a broader range of maternity and obstetrics services, employ more highly skilled staff and are located within large hospitals offering back-up support services such as intensive care units. These facilities are more costly to set up and run, and are intended for those women and babies at highest risk.

Ideally, women at lower levels of risk should receive their maternity care at less specialised facilities. But there is no mechanism to ensure that women sort themselves among facilities according to their risk status.

One way to influence the choice of providers by women is to build more lower-level facilities, thereby reducing distance and travel costs for patients. At the margin, this might change the balance between preferences in favour of continuity of care and away from better equipped but more distant facilities for delivery. Chapter 3 tries to answer the following research question:

- Does opening more midwife-led maternity units improve quality of care and women's welfare?

This chapter evaluates the effect of introduction of three new midwife-led maternity units on a set of outcomes, including: continuity of care, C-sections, maternal health complications and women's consumer surplus. I use synthetic difference in difference methods to evaluate the policy of opening new midwife-led maternity units on health care indicators and conditional logit for evaluating its effects on women's welfare.

Chapter 3 shows that new midwife-led maternity units increase women's welfare measured in consumer surplus, decrease the demand for higher level providers, and increase the demand for lower level providers but are generally ineffective in improving health outcomes. However they seem to have some effects on C-sections and health outcomes when introduced in a geographical area with no competing midwife-led providers nearby.

C-section rates are increasing in most countries (Betrán et al., 2016a; Chen, 2013; Savage, 2000; Lancet, 2018; Visser et al., 2018), including Peru. They are argued to be a serious public health problem (Carr and Riesco, 2007; Kaplanoglu et al., 2015; Ajeet and Nandkishore, 2013). As women's health risk is not increasing at the same rate as C-sections (Anderson and Lomas, 1985; Lancet, 2018), suggestion overuse of C-sections (Boerma et al., 2018; Betrán et al., 2018), the World Health Organization recommends C-sections only be performed for medically indicated reasons (World Health Organization, 2015).

On the supply side, the natural candidate is to study the phenomena under the physician-induced demand framework. This framework is generally attributed to Evans (1974) and is defined by McGuire (2000, p.504) "*Physician-induced demand (PID) exists when the physician influences a patient's demand for care against the physician's interpretation of the best interest of the patient*". There are several channels studied in the literature: physicians can respond to changes in physician-to-population ratios (Cromwell and Mitchell, 1986; Fuchs, 1978; Léonard et al., 2009), they value more defensive medicine (Danzon, 2000; Kessler, 2017), and obstetricians can perform C-sections due to convenience and management of their time and workload (Johnson, 2014). Chapter 4 examines the following research questions:

- Does the ratio of obstetricians to the volume of child deliveries in a maternity unit affect its C-section rates?

- Do obstetricians up-code co-morbidities to justify their decision to perform C-sections?
- Does the ratio of obstetricians to the volume of child deliveries per maternity unit affect maternal health outcomes?

A high obstetricians/child deliveries ratio has a direct effect on health outcomes due to a greater availability of staff improving outcomes for vaginal and C-section deliveries to perform better procedures and an indirect effect on average health outcomes via the mix of procedures. In Chapter 4 I use linear probability models with provider and obstetrician fixed effects to investigate whether the ratio of number of obstetricians/child deliveries affects C-sections, upcoding and women's health outcomes.

I find that a higher ratio of obstetricians to deliveries increases the C-section rate and obstetricians justify their decisions to perform more C-sections by using co-morbidity codes that are easy to manipulate such as foetal stress or prolonged pregnancy. Whilst most health outcomes are improved when there are more obstetricians per delivery, women's puerperal infections are increased.

Chapter 4 not only contributes new evidence to the physician-induced demand literature, but also to the literature on volume and health outcomes that mostly focuses on between-hospital variation (Hamilton and Hamilton, 1997; Hamilton and Ho, 1998; Barker et al., 2011; Hentschker and Mennicken, 2018). Using a daily within-hospital variation I show when there is greater supply, defined as the number of obstetricians on duty per child delivery per maternity unit per day, there are more C-sections induced, that obstetricians justify this by upcoding co-morbidities and that this has mixed effects on maternal health outcomes. This last effect is because more obstetricians on duty can potentially change the mix of delivery types, and affect health outcomes for delivery types.

Since the ratio of obstetricians/volume of child deliveries affects both C-sections and health outcomes, and as it is important to separate any effect of C-sections on health outcomes, Chapter 5 investigates the following question:

- Do caesarean sections affect maternal health outcomes?

I use an instrumental variable, difference in distances to different provider types, in a biprobit setting to investigate the effect of C-sections on women's health outcomes in chapter 5.

Chapter 5 suggests a causal link path between C-section and poor health outcomes, especially for haemorrhage, which is one of the main causes of maternal mortality worldwide, and experienced mainly by low-risk women following a C-section.

Together, the policy implications are that decisions on investment in new midwife-led units should be directed to areas with obstetrician-led providers with no competing midwife-led providers nearby (Chapter 3). Chapter 4 suggests that the use of codes that are easy to manipulate should be more clearly regulated.

1.2 Institutional background of the Peruvian maternity health care system and data

1.2.1 The Peruvian health care system

In 2015, Peru had a population of around 32 million of which 43% were insured by the Comprehensive Health Insurance program of the Health Ministry called Seguro Integral de Salud-SIS; 25% were insured by the El Seguro Social de Salud-ESSALUD; 5% by others (private, armed forces and police) and 27% were uninsured. (Instituto Nacional de Estadistica e Informatica del Peru, 2015b). The uninsured population has been decreasing in the past 10 years mainly with the increase of SIS population, as depicted in Figure 1.1.

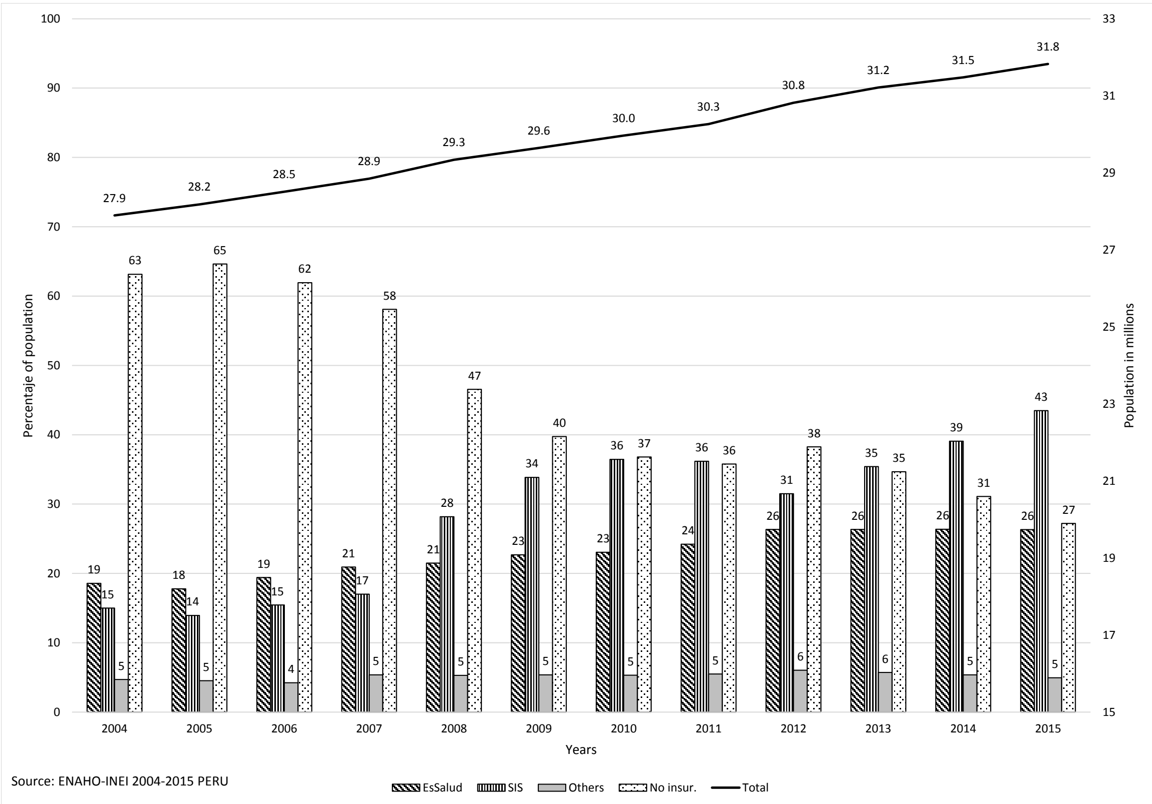

Figure (1.1) Peru 2004-2015: Population and insurance

The Figure 1.2 summarises the health system in Peru. There are financiers and providers that work whiting two sub-systems, public and private. Therefore, there are public financiers and public providers and private financiers and private providers.

As shown above, in the public sector the main financiers are the Seguro Integral de Salud-SIS, which is tax based, and El Seguro Social de Salud-ESSALUD, financed by income taxes. Apart from these there are small financiers for the police and the armed forces (1.7% of the population). The private financiers altogether cover 2.7% of the population (Instituto Nacional de Estadistica e Informatica del Peru, 2015b).

SIS is a system established in 1999, primary conceived as a health financier for people on low incomes. It also covers other specific groups such as children born since 2015 regardless of their family income and former victims of violence by the Peruvian terrorist groups from 1980 to 2000.

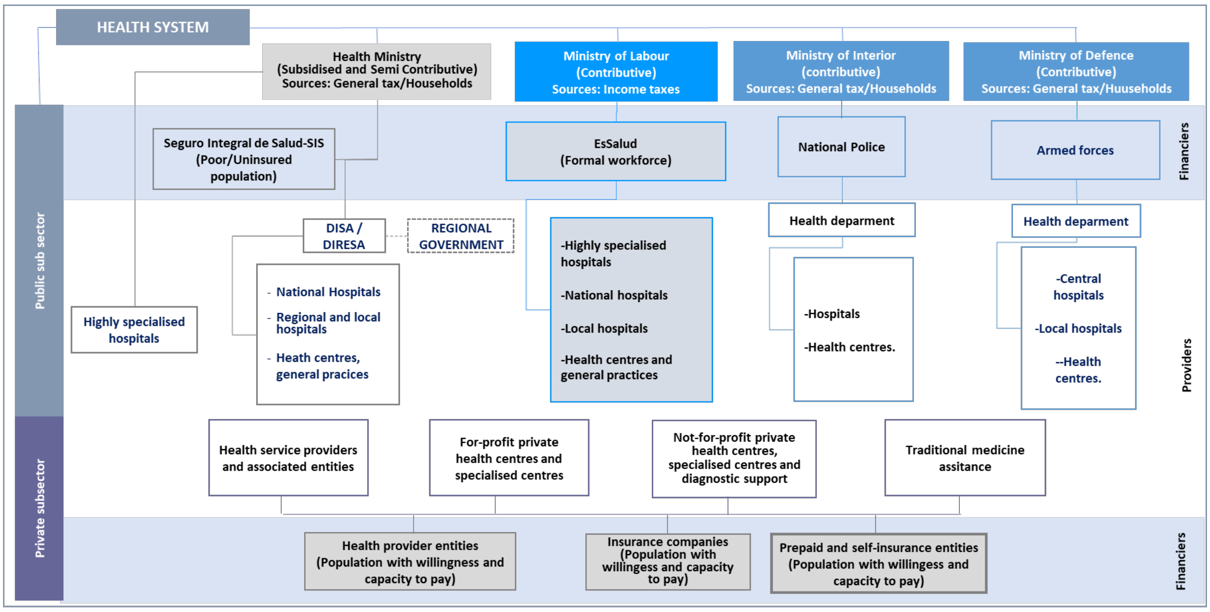

Figure (1.2) The Peruvian health system

SIS is financed from general taxes and is used mainly to finance public health facilities.

From the provider's perspective, public health facilities are also financed by general taxes administered by regional governments and some of them, in the case of Lima, directly by the Health Ministry. For that reason they sell their services to the general public at subsidised prices. SIS buys health services mainly from public health facilities, which are not their property nor are they under its direct administration. The SIS insured population is treated without charge.

In summary, public health facilities have been financed by three sources: firstly by the Health Ministry/Regional Government with general tax resources, secondly by SIS that also has its resources from general taxation, and third by the general (non insured) public that paid a subsidised price.

ESSALUD in turn is financed by a compulsory contribution from the formal workforce. Almost all of ESSALUD finances its own hospitals under its control, and work as a closed circuit with ESSALUD hospitals only providing care to its insured population. The Police and the Armed Forces work also similar to ESSALUD, their insurer population correspond to the police and the military and their families and their providers work as a close circuit not attending other population.

The private sector insurers covers population with willingness and capacity to pay and their providers sell services to their insured population and the general public.

The main payment systems are the global budget in the Health Ministry (SIS), ESSALUD, the Police and the Armed Forces, and fee-for-service in the private sector. There have been some previous attempts to introduce activity-based payment mainly in the SIS, but it has not been fully implemented. The Health Ministry/Regional Governments have around 6000 facilities and ESSALUD about 500 facilities across the country, which are organised in categories, with higher levels providing more complex services.

The Table 1.1 details the percentages of deliveries in Lima in 2015 by type of insurer and delivery place (Instituto Nacional de Estadistica e Informatica del Peru, 2015a).

Table (1.1) Percentage of deliveries by insurer and place of delivery in Lima 2015

		INSURER					Overall
		SIS	ESSALUD	Police-Armed Forced	Private	Uninsured	
DELIVERY PLACE	Health Ministry	33%	8%	0%	0.4%	11%	52%
	ESSALUD	1%	19%	0%	0.3%	3%	24%
	Police-Armed Forced	0.0%	0.1%	1%	0.0%	0.1%	1%
	Private	2%	10%	0.2%	2%	4%	19%
	Home delivery	0.3%	0.3%	0.0%	0.0%	0.2%	1%
	Others	1%	1%	0.0%	0.1%	0.3%	2%
	Overall	37%	38%	1%	3%	20%	100%

Note: Source: ENDES-INEI 2015

The rows show where women give birth. The first row, last column, shows that more than half of deliveries were performed in the Health Ministry's providers (52%), followed by ESSALUD (24%) and private providers (19%).

The columns show to which insurer these women were affiliated, not if these insurers actually paid for the delivery, and as women can be affiliated to more than one insurer the table considers only the first insurer declared. For example 37% of women where covered by SIS[1] (first column, last row), but some of them choose home delivery or private providers, which are likely to be paid by out-of pocket family expenditure. Even though these women have SIS they do not choose to use their insurer.

This thesis focuses on the share of women that is covered with SIS and uses Health Ministry's public providers, this accounts for about 33% of deliveries in Lima as is shown in the first row, and first column of Table 1.1.

1.2.2 SIS and public providers in Lima

In this subsection I describe the administrative data, used throughout the thesis, from the Seguro Integral de Salud (SIS) where there are no charges for antenatal care and child delivery for insured women.

Antenatal care is delivered in Lima in 366 facilities, 50 of which are also equipped for child delivery. The Health Ministry of Peru (Ministerio de Salud del Peru, 2004) has grouped the health facilities into eight categories indicative of their structural capabilities, ordered from the least to the most specialised: I-1, I-2, I-3, I-4, II-1, II-2 III-1 and III-2.

The initial three levels were designed to provide only antenatal care; level I-4 contains the midwife-led maternity units with vaginal delivery capability. At the end of the year 2015, there were 36 midwife-led maternity units. The remaining three levels, with 14 providers, are obstetrician-led maternity units which along with vaginal deliveries can also provide C-sections. Figure 1.3 shows the geographical distribution of providers in Lima.

These providers are officially organised geographically in networks and micro-networks (Ministerio de Salud del Peru, 2001) which are in turn inside territorial divisions. In the case of Lima there are 45 micro-networks inside 10 networks inside three territorial divisions. Level I-1 to I-4 providers are administered by micro-networks, level II-1 and II-2 by networks, level III-1 by territorial divisions. The only level III-2 provider is the national centre for highly complex cases.

[1] This percentage is different from the 43% of coverage of the general population presented before, this is because deliveries are a subset of the general population.

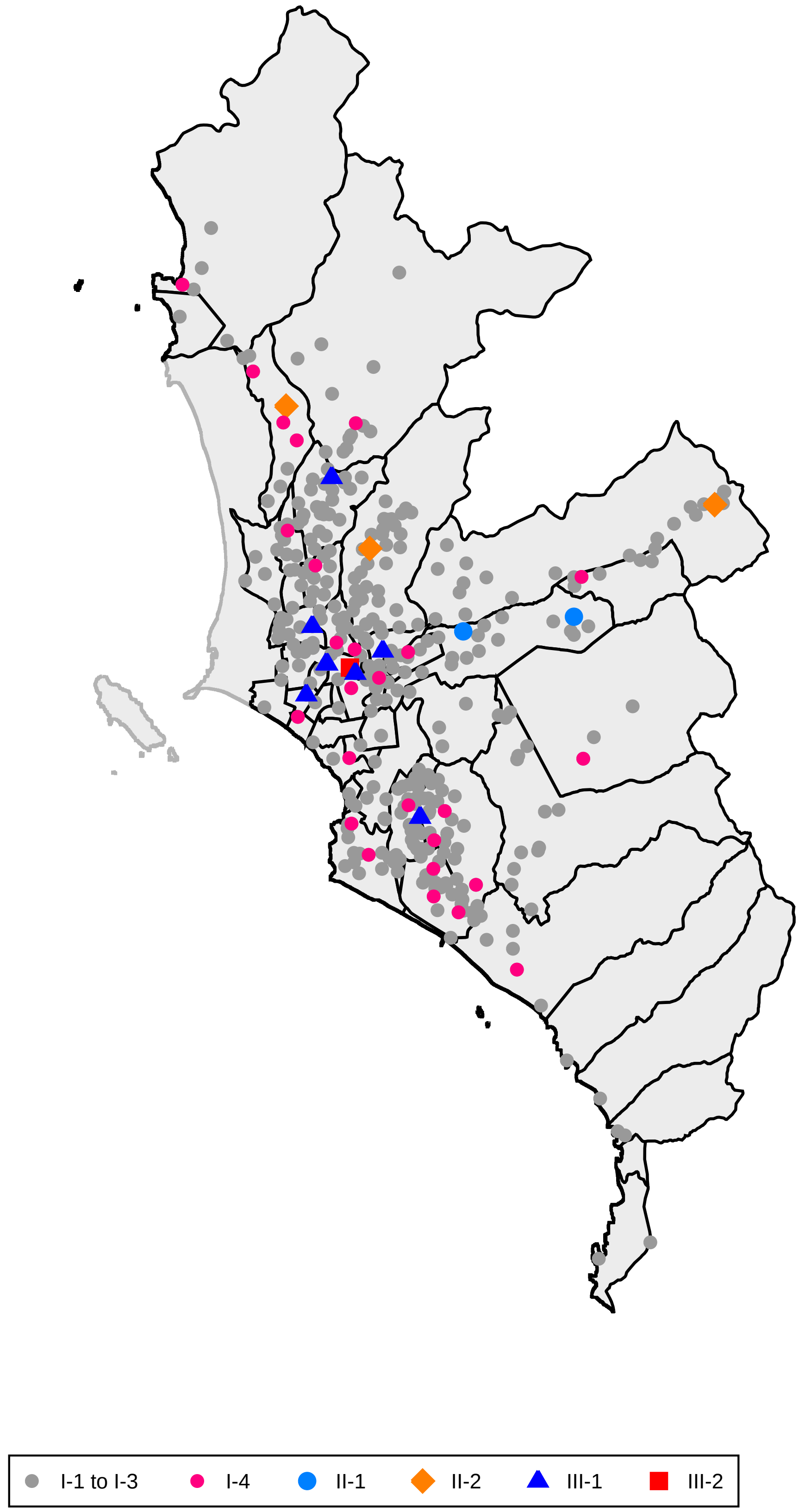

Figure (1.3) Distribution of public health facilities in Lima, Peru

Table 1.2 presents the minimum requirements for each level as defined by the Peruvian Health Ministry. Level I-1 only requires itinerant visits of physicians and to be open up to 6 hours per day. For level I-2 the requirement is having general physicians for 6 to 12 hours per day. Level I-3 should have general physicians for at least 12 hours and also have a laboratory. Level I-4 is the midwife-led maternity unit provider, the minimum level for child delivery, and must have physicians covering at least two medical specialties[2].

Table (1.2) Providers' characteristics by level

Minumum structural capabilities by provider's level

Level	General physician	Laboratory	Physician specialty	Emergency	Theatre	ICU	Research	Normative capacity
I-1	Itinerant							
I-2	6-12 hrs							
I-3	12 hrs	Yes						
I-4	12 hrs	Yes	2 Specialties					
II-1	12 hrs	Yes	6 Specialties	Yes	Yes			
II-2	12 hrs	Yes	All	Yes	Yes	General		
III-1	12 hrs	Yes	All + Subspec.	Yes	Yes	Specialist	Yes	
III-2	12 hrs	Yes	All + Subspec.	Yes	Yes	Specialist	Yes	Yes

Source: Ministry of Health, Peru (2004)

A theatre is required from level II-1 and Intensive Care Units (ICU) from level II-2. Level III-1 have the full range of medical specialties, medical sub-specialties, specialized ICU and research capacity, while the highest level III-2 is specialised in perinatal maternal medicine and the Health Ministry established it's normative capacity[3], and as such is the national authority which develops nation wide policies and norms (guidelines) related to perinatal and maternal care.

Table 1.3 shows the annual average number of midwives, general physicians and gyneco-obstetricians in each facility level. The number of midwives increases from level I-1 up to the level I-4, and then decreases because higher risk antenatal care and child delivery is provided by gyneco-obstetricians.

Table (1.3) Human resources, bed days and child deliveries per year by provider's level type

		Midwives		General physicians		Obstetricians		Bed days		Child deliveries	
Level	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	% c-sections
I-1	18	2.9	(1.80)	3.8	(2.29)						
I-2	147	3.4	(2.19)	3.6	(2.29)						
I-3	151	4.1	(2.05)	6.3	(3.07)						
I-4	36	11.9	(4.35)	14.7	(5.90)	1.6	(1.98)	118	(255.6)	324	0%
II-1	2	8.3	(8.83)	10.6	(3.60)	15.6	(7.75)	3,898	(2,236.3)	2,206	25%
II-2	3	5.9	(8.99)	29.0	(20.43)	16.6	(6.55)	6,308	(3,325.2)	3,066	36%
III-1	8	2.9	(5.88)	49.2	(45.71)	36.6	(10.38)	12,281	(4,604.8)	3,769	46%
III-2	1	0		15.6	(16.24)	91.4	(14.91)	26,678	(22,023.7)	8,789	40%
Total	366										

Source: Estimated using Ministry of Health (2016) dataset 2011-2015

Similarly the number of general physicians involved in maternity care increase up to level III-1 and then decreases at the highest level. The average number of obstetricians, maternity bed days, deliveries per year and C-section rates also increase from level I-4 to III-2.

[2]In the dataset there are nominally 10 providers with category I-3 that were performing regular child deliveries, all of them are considered as belonging to the level I-4 in the analysis because they already had the minimum infrastructure and staff required to provide for child deliveries. All of them are included in the modelling as level I-4.

[3]Ministerio de Salud del Peru (2010) establish as one of the main functions of this highly specialised provider "Permanently innovate the norms, methods and techniques for specialized and highly specialized attention to women's reproductive health with emphasis on neonatal maternal care".

The official classification is a signal of the structural quality differences between health facilities due to physical and technological capabilities and human resources. These may influence a woman's choices for antenatal care and for child delivery.

Physicians hired by public providers receive a salary that depends on their specialty and experience not on the number of women that they may attend, so any financial incentive is indirect. The hospital receive public funds that depend on the historical budget and also on the number and mode of deliveries.

1.2.3 The data

The initial dataset contains information on 326,033 women who received maternity care in Lima, over a five-year period from 2011 to 2015 (Ministerio de Salud del Peru, 2016).

Table 1.4 provides the details of the data cleaning process. About 0.9% of the observations in the initial dataset were dropped due to patient ID errors, 0.1% for errors in staff ID, 0.8% for duplications, 0.3% for errors in duration of length of stay and mother's age, 0.4% due to miscoding in procedures and dates, 0.1% because they were referred from outside Lima, making the distance travelled unusually great, and 0.02% because delivery was in a facility not equipped for delivery.

Table (1.4) Starting and analytical sample

	N	%
Raw data for deliveries	326,033	
Patient's ID errors	2,998	0.9%
Staff's ID errors	393	0.1%
Duplications	2,701	0.8%
Duration and patient's age errors	924	0.3%
Miscoding in procedure and dates	1,271	0.4%
Patient referenced from providers outside Lima	371	0.1%
Sporadic deliveries in providers equipped only for antenatal care	70	0.02%
After cleaning	317,305	97.3%
Cleaned dataset	317,305	
With information on distances	287,460	90.6%

I have data for 280 days[4] prior to delivery (pregnancy period) to 28 days post discharge (puerperium period[5]) for deliveries between 1 January 2011 and 31 December 2015.

It was not possible to link mothers to babies due to anonymised ID, so I do not consider in this thesis child health outcomes.

I cannot compute distances from home to health facilities as the home address is not recorded in the dataset. Instead I linked the 317,305 cleaned observations on deliveries, using each patient's anonymised ID, to an additional 2,452,328 records of their use of healthcare, other than for maternity care. I then use the address of the facility which was most frequently used by the women for non-antenatal and child-delivery care as a proxy for their address. I use straight line distances from the women's proxy addresses to all providers for 287,460 observations.

[4]For women who have more than one delivery in the period of analysis and where the gap between deliveries is less than 280 days, I define the pregnancy period as 240 days before delivery.

[5]The puerperium period is technically up to 28 days after child delivery. On average I include from 28 days up to 30 days, as the average length of stay is 2.4 days, this is because I only have the day of admission and the discharge.

1.3 Structure of this thesis

In Chapter 2 I model women's choice of health providers for antenatal care and child delivery, and how this is affected by continuity of care, providers' structural quality, and distance.

In Chapter 3 I examine the effect of opening new midwife-led maternity units. Overall this causes an increase in the use of lower level providers and a decrease in the use of higher level providers, impacting welfare, and to a lesser extend, reducing C-sections and improving health outcomes.

In Chapter 4 I test whether the rate of C-sections per day are determined by the ratio of obstetricians/child deliveries. I also test to see if this ratio explains upcoding and health outcomes.

In Chapter 5 I examine the effect of C-sections on maternal health outcomes, using distances as instrumental variables.

Chapter 6 summarises and reviews the main finding of the thesis.

Chapter 2

Choice of providers: continuity, structural quality, and distance

2.1 Introduction

It is recommended that expectant mothers are cared for by the same provider throughout the pregnancy through to birth and post-natal care (Hodnett, 2000), thereby ensuring continuity of maternity care. But some women that receive their antenatal care locally are prepared to travel further afield when it comes to giving birth. It seems that women are prepared to accept less continuity of care and incur higher travel costs, in order to have their child delivered in places with better delivery facilities.

It is argued that continuity of care in midwife-led units, providing both antenatal and child delivery care, safely reduces caesarean sections (C-sections) (McLachlan et al., 2012; Tracy et al., 2013) and improves health outcomes (Betrán et al., 2018; Lancet, 2018; Wiklund et al., 2018). A recent Cochrane systematic review recognises the rising C-sections problem and evaluates non-clinical interventions for reducing unnecessary caesarean sections (Chen et al., 2018). C-sections particularly are associated with haemorrhages and critical care admissions (Cook et al., 2013), hysterectomy, blood transfusions, adhesions, and surgical injury (Marshall et al., 2011). C-section rates higher than 10% at population level seems not to reduce maternal or neonatal mortality rates (Ye et al., 2016). However, the NICE guidelines recognise that more evidence is needed, as the available evidence is low or very low quality, and some of it has conflicting findings (National Institute for Health and Care Excellence - NICE, 2011).

In this chapter I examine the factors which influence women's choice of antenatal and delivery provider. I focus on maternity care in Lima, where health care is fully subsidised, with women facing a zero price at point of use. Following Donabedian's schema (Donabedian, 2005), I consider continuity of maternity care as a measure of process quality and the staffing and equipment arrangements at maternity facilities as a measure of structural quality. I examine the trade-off that expectant mothers make between process and structural quality, with distance acting as a price because of the travel costs involved.

58% of expectant mothers in Lima live near to a midwife-led maternity unit, even if they receive antenatal care locally, 71% bypass their local facility to give birth elsewhere, further away from where they live. Previous research has found evidence that patients travel further to receive higher quality (Luft et al., 1990), measured as health gain from specific treatments (Gutacker et al., 2016; Gaynor et al., 2016) and structural quality (Roh and Moon, 2005; Varkevisser and Geest, 2007; Kanté et al., 2016). This literature examines the choice of providers for a single treatment, rather a series of treatments and how this is affected by structural or outcome measures of quality of providers.

Common to this literature is consideration of a single dimension of quality, with the trade-off being between quality measured on outcomes (eg. mortality, emergency readmissions) and distance. In contrast, this chapter examines the factors affecting the mix of providers chosen for two types of treatment (antenatal and delivery) and how this is affected by a process measure (continuity), as well as a structural measure of quality. The contribution of this chapter to the literature is to examine the extent to what women are prepared to trade-off process quality (continuity) in midwife-led maternity units, against delivery in better equipped facilities with greater travel cost.

I analyse patient-level administrative data relating to 228,948 child deliveries between 2011 to 2015 in Lima. All patients were covered financially by the Seguro Integral de Salud-SIS, a public health insurance programme. Maternity care was provided in 366 different health facilities, of which 50 are equipped to provide child delivery as well as antenatal care.These facilities are grouped into eight levels ordered from the least to the most specialised structural capabilities: I-1, I-2, I-3, I-4, II-1, II-2, III-1 and III-2. The initial three levels were designed to provide only antenatal care, and level I-4 are midwife-led maternity units with vaginal delivery capability, while the remaining four levels are obstetrician-led maternity units with C-sections capabilities. Providers are officially organised geographically in 10 networks and 45 micro-networks. The map plotted in Figure 1.3 in the Introduction of this thesis displays the geographical distribution of providers in Lima.

I use two definitions of continuity of care: a) network continuity: a woman chooses antenatal care and child delivery from providers inside the same micro-network; or as there are some micro-networks that have no provider with child delivery capabilities, a woman chooses the closest delivery unit inside the same network. b) Provider continuity: a woman chooses the same provider for antenatal care and child delivery. Additionally I classify continuity of care according to the type of provider: a) Midwife-led continuity of care if the antenatal and delivery provider is level I-4 and b) Obstetrician-led continuity of care where the antenatal and delivery provider are providers level II-1, II-2, III-1 and III-2.

Most delivery providers are midwife-led maternity units (see Table 1.3 in the introduction of the thesis). I measure the trade-off behaviour for quality by women's choice of type of provider when women choose a midwife-led maternity unit for antenatal care and forego continuity of care by choosing an obstetrician provider for the time of child delivery. I estimate a conditional logit model to examine factors associated with whether mothers choose continuity of care. These factors include the structural quality of the child delivery provider, the structural quality of the antenatal care provider, distances to antenatal care and child delivery providers, and a set of patient's characteristics including measures of maternal risk.

The remainder of this chapter is structured as follows. In Section 2.2 I set out the conceptual and empirical approach, section 2.3 presents the data and descriptive statistics and section 2.4 reports the results. Concluding remarks are presented in section 2.5.

2.2 Conceptual and empirical framework

2.2.1 Theoretical set-up

Consider a linear city with length of one, in a Hotelling framework (Hotelling, 1990; Armstrong and Wright, 2007). The population of pregnant women is distributed uniformly along the city. Woman $i = 1, \ldots, I$ choose between two types of hospital $k = 1, 2$ where 1 is a midwife-led maternity unit (M), generally regarded as a lower structural quality provider and 2 an obstetrician-led maternity unit (O), regarded as a higher structural quality provider with operating theatres and back up units such as intensive care units.

Women realise there are two choices at two consecutive times $t = 1, 2$. In the first period she chooses antenatal care and in the second period, child delivery. I write the following utility function for choice of each type of provider by woman i:

for the midwife-led maternity unit

$$U_{it}^{M}(\delta, t) = v_t^M - c\delta^2, \forall t = 1, 2 \tag{2.1}$$

and for the obstetrician-led maternity unit

$$U_{it}^{O}(\delta, t) = v_t^O - c(1-\delta)^2, \forall t = 1, 2 \tag{2.2}$$

where v_t^M is the intrinsic utility for choosing the midwife-led maternity unit for antenatal care $t = 1$, and child delivery $t = 2$. v_t^O is the intrinsic utility function for choosing the obstetrician-led provider for antenatal care $t = 1$, and child delivery $t = 2$. c is the travel cost, δ is the distance from location of woman i to the midwife-led maternity unit and $1 - \delta$ the distance to obstetrician-led maternity unit.

Assuming v_t^M and v_t^O are sufficiently high that all women get positive utility from either provider the number of women who choose each type of provider is determined by the two following Hotelling formulae:

$$\delta_t^M = \frac{1}{2} + \frac{v_t^M - v_t^O}{2c}, \forall t = 1, 2 \tag{2.3}$$

$$\delta_t^O = 1 - \delta_t^M = \frac{1}{2} + \frac{v_t^O - v_t^M}{2c}, \forall t = 1, 2 \tag{2.4}$$

where δ_t^M and δ_t^O are the distance where women are indifferent between choosing midwife-led and obstetrician-led maternity units at time $t = 1, 2$ respectively.

In cases where women value both providers equally for antenatal care and child delivery, $v_1^M = v_1^O = v_2^M = v_2^O$, half of the women choose the midwife-led maternity unit and the other half the obstetrician-led maternity unit for antenatal care and child delivery. Even though continuity of care has no intrinsic value, there is continuity of care for all women, assuming that those who are indifferent between the providers always chose midwife-led provider.

In cases where women are indifferent to both types of provider for antenatal care,$v_1^M = v_1^O$, but places a higher value on giving birth in obstetrician-led maternity units, $v_2^M < v_2^O$, then while equal numbers will choose each type of provider for antenatal care, $\delta_1^M = \delta_1^O$, more than half will choose the obstetrician-led provider for child delivery $\delta_2^M < \frac{1}{2} < (1 - \delta_2^O)$. This is because it is assumed that the intrinsic benefit to expectant mothers from obstetrician-led providers is greater than from midwife-led providers.

The difference $\delta_1^M - \delta_2^M > 0$ is the fraction of women who discontinue their care in midwife-led maternity units for the prospect of better quality at the time of child delivery, paying for extra distance.

In this case, the model predicts that there will be three groups of women. The first group, women who choose combinations $\{M, M\}$ the midwife-led provider for antenatal care and child delivery, second group, women who choose combination $\{O, O\}$ the obstetrician-led provider for antenatal care and child delivery, and the third group, women who choose combination $\{M, O\}$ midwife-led provider for antenatal care and obstetrician-led provider for child delivery.

The model predicts that an increase on travel cost will increase continuity of care. From equations (2.3) and (2.4), the difference in values between providers becomes irrelevant, and the population share of women as $c \to \infty$ will tend to 50% for each maternity unit and continuity of care will tend to 100%.

In this simple model women do not place any value directly on being treated by the same provider in both periods, i.e. they have no utility from continuity of care. Even if an additional pay-off for continuity of care is included it does not change the main predictions of this basic model. Consider the following slight modification for women's pay-off:

for a midwife-led maternity unit

$$U_{i1}^M = v_1^M - c\delta^2; U_{i2}^M = v_2^M - c\delta^2 + B^M \tag{2.5}$$

and for an obstetrician-led maternity unit

$$U_{i1}^O = v_1^O - c(1-\delta)^2; U_{i2}^O = v_2^O - c(1-\delta)^2 + B^O \tag{2.6}$$

Where B^M and B^O are the pay-offs for continuity of care in midwife-led maternity units and in obstetrician-led maternity units, respectively.

First I find the boundary where women are indifferent between choosing twice midwife-led maternity with continuity of care and choosing antenatal care with the midwife-led maternity unit and child delivery in the obstetrician-led unit with no continuity of care. Equating the utilities from those choices gives:

$$\delta^{MM} = \frac{1}{2} + \frac{v_2^M - v_2^O + B^M}{2c} \tag{2.7}$$

where δ^{MM} is the distance that defines the subset of women who choose continuity of care in the midwife-led maternity unit.

Second, I solve to find the boundary between the women who are indifferent between choosing twice the obstetrician-led maternity with continuity of care and choosing antenatal care with the midwife-led maternity unit and for child delivery the obstetrician-led unit with no continuity of care:

$$\delta^{OO} = \frac{1}{2} + \frac{v_1^M - v_1^O - B^O}{2c} \tag{2.8}$$

where δ^{OO} is the distance that defines the subset of women that choose continuity of care in the obstetrician-led maternity unit.

Note that if $B^M = B^O = 0$, this model collapses to the model where continuity of care is of no value.

Plausibly it is assumed $v_2^M - v_2^O + B^M \leq v_1^M - v_1^O - B^O \leq 0$. This is that the difference in utility for choosing between the obstetrician-led provider for child delivery and the midwife-led provider for child delivery plus the gains in utility for continuity of care in the midwife-led maternity unit is greater or equal, in absolute values, than the difference in utility for choosing between the obstetrician-led provider for antenatal care and the midwife-led provider for antenatal care plus the utility from continuity of care in the obstetrician-led provider. This yields $\delta^{MM} \leq \delta^{OO} \leq \frac{1}{2}$.

Then the fraction of women $MM = \delta^{MM}$ choose continuity of care in the midwife-led maternity unit, the fraction $OO = 1 - \delta^{OO}$ choose continuity of care in the obstetrician-led maternity unit and the fraction $MO = \delta^{OO} - \delta^{MM}$ choose the midwife-led maternity unit for antenatal care, discontinue their care, and choose the obstetrician-led provider for child delivery. The bottom part of Figure 2.1 illustrates this result.

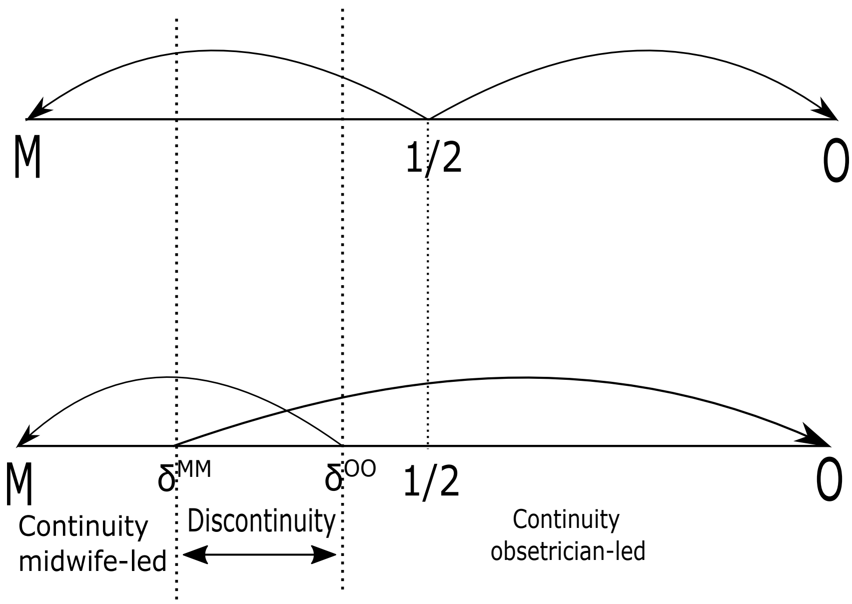

Figure (2.1) Trade-off continuity for higher structural quality

Note: Upper panel: Case where women have the same intrinsic utility for antenatal care and child delivery in either, midwife-led maternity unit (M) or obstetrician-led maternity unit (O). Lower panel: case where the intrinsic utility for child delivery is higher for child deliveries in obstetrician-led providers. The discontinuity segment represents the proportion of women who choose antenatal care in M but forego continuity of care and choose O for child delivery.

This means that more than half of women will choose continuity of care with obstetrician-led providers, less than half will choose continuity of care in midwife-led maternity units and the remainder will trade-off continuity of care in midwife-led maternity units for the prospect of higher quality in obstetrician-led maternity units.

I obtain the following comparative statics for the effect of an increase in travel cost on these fractions.

$$\frac{\partial \delta^{MM}}{\partial c} = \frac{1}{4c^2}[-v_2^M + v_2^O - B^M] > 0 \tag{2.9}$$

$$\frac{\partial \delta^{OO}}{\partial c} = \frac{1}{4c^2}[-v_1^M + v_1^O + B^O] > 0 \tag{2.10}$$

Both of these are positive, which shows that the effect of an increase in the travel cost will increase both thresholds that determine the share of women who choose both providers. This implies an increase in continuity of care for midwife-led maternity units and a decrease in continuity of care in obstetrician-led maternity units. Equations (2.7) and (2.8) imply that as $c \to \infty$, there will be 50% of continuity of care in each type of maternity unit.

Additionally,

$$\frac{\partial \delta^{MM}}{\partial B^M} = \frac{1}{2c} > 0 \tag{2.11}$$

$$\frac{\partial \delta^{OO}}{\partial B^O} = -\frac{1}{2c} < 0 \tag{2.12}$$

which implies that an increase in women's utility for midwife-led continuity of care moves to the right δ^{MM}, therefore increasing the proportion of women choosing midwife-led providers for antenatal care and child delivery as $MM = \delta^{MM}$. Likewise, an increase in women's pay-off for obstetrician-led continuity of care moves δ^{OO} to the left, therefore increasing the proportion of women choosing obstetrician-led providers for antenatal care and child delivery as $OO = 1-\delta^{OO}$.

The model predicts that women do not choose $\{O, M\}$ which yields $v_1^O + v_2^M - c(1-\delta)^2 - c\delta^2$, since choosing $\{M, O\}$ gives higher utility $v_1^M + v_2^O - c(1-\delta)^2 - c\delta^2 > v_1^O + v_2^M - c(1-\delta)^2 - c\delta^2$ under the plausible assumption that $v_1^O - v_1^M < v_2^O - v_2^M$. So three patterns are predicted by the Hotelling model, $\{M, M\}$,$\{O, O\}$ and $\{M, O\}$. I would only observe $\{O, M\}$ if women revise their estimates of v_2^O,v_2^M after they have experienced antenatal care or if the delivery turns out to be an emergency with a very high travel cost so that a woman will choose the nearest delivery provider irrespective of the antenatal choice or if there is a richer specification of the utility functions. An extension for the theory model which allows all four possible combinations of choice is developed in the appendix B of this Chapter.

2.2.2 Empirical specification

In this subsection I describe the empirical specification for analysing the choices about where to receive antenatal care and where to give birth, recognising that women trade-off continuity of care and travel distance. In doing so, I apply the simplified theoretical approach to study a complex empirical choice set. Here the choice set is not composed of by providers as such but by a particular arrangements of providers. Then the choice set is a set of possible combinations of antenatal care and child delivery providers inside a given distance, where I can identify among them the combinations that offer network continuity or provider continuity of care. I then analyse whether women choose those combinations or other combinations that imply a trade-off of continuity of care against higher structural quality providers and higher travel cost.

Specifically, I estimate random utility models (McFadden, 1973) for woman $i = 1, \ldots, I$ gaining utility from choice of a combination $k \in \{a, b\}$ of an antenatal care provider $a(a = 1, \ldots, N^A)$ and child delivery provider $b(b = 1, \ldots, N^B)$ at time $t = 1, \ldots, T$. The simple model is

$$
\begin{aligned}
U_{ik} &= V_{ik} + \nu_{ik} \\
&= C_i\beta_C + q_i^{chd}\beta_{q_{chd}} + q_i^{anc}\beta_{q_{anc}} + D_{ik}^{anc}\beta_{D^{anc}} + D_{ik}^{chd}\beta_{D^{chd}} + \nu_{ik}
\end{aligned}
\tag{2.13}
$$

V_{ik} depends on a vector of quality measures that include continuity of care $C_i \in \{0, 1\}$, and structural quality for child delivery q_i^{chd} that takes the value of 1 if woman i chooses child delivery in an obstetrician-led maternity unit and zero in a midwife-led maternity unit, with analogously constructed structural quality for antenatal care q_i^{anc}. Distance for antenatal care D^{anc} and for child delivery D^{chd} and ν_{ik} is a random utility component with independent and identical extreme value distribution.

In the main model I allow the utility from continuity to depend on whether the woman chooses continuity in midwife-led or obstetrician-led provider:

$$
\begin{aligned}
U_{ik} &= V_{ik} + \nu_{ik} \\
&= C_i * (1 - q_i^{chd})\beta_M + C_i * q_i^{chd}\beta_O + q_i^{chd}\beta_{q_{chd}} + q_i^{anc}\beta_{q_{anc}} \\
&+ D_{ik}^{anc}\beta_{D^{anc}} + D_{ik}^{chd}\beta_{D^{chd}} + \nu_{ik}
\end{aligned}
\tag{2.14}
$$

Equation (2.14) allows utility from continuity to depend on utility in obstetrician and midwife-led units, where $C_i * (1 - q_i^{chd})$ and $C_i * q_i^{chd}$ are continuity of care in midwife-led and obstetrician-led maternity units respectively. I estimate both specifications by conditional logit.

The coefficients are marginal utilities but are unique only up to a proportional (scale) transformation. I divide coefficients by the coefficient on distance to delivery provider to measure willingness to travel (WTT). Thus the willingness to travel for continuity of care in a midwife-led maternity unit can be expressed as

$$
WTT = -\frac{\beta_M}{\beta_{D^{chd}}} \tag{2.15}
$$

The standard errors in equation (2.15) are estimated by the delta method (Hole, 2007).

2.3 Data and descriptive statistics

2.3.1 Sources and variables

I use administrative data from the Peruvian public health insurance programme. The data records child deliveries in 366 facilities officially organised geographically in 45 micro-networks, 10 networks and three territorial divisions. Providers are grouped into eight categories indicative of their structural capabilities, from the lowest to the highest I-1, I-2, I-3, I-4, II-1, II-2, III-1, III-2, and child deliveries can be carried on from level I-4, the midwife-led provider, onwards.

The data comes from Lima and the period under analysis spans from 2011 to 2015. From the 317,305 cleaned observations available I identify 253,124 women who have information on antenatal care usage and the proxy variable of home address. The details of the dataset and the cleaning process are in the introductory chapter of this thesis.

Micro-networks are defined by geographical features, such as the existence of hills, rivers and transport connections. Networks are an aggregation of micro-networks and as such the differences in characteristics are stronger. For example there is a pronounced hill between the San Juan de Lurigancho network and the Tupac Amaru network, both in the north-east of Lima. The linear distances alone do not reflect travel time. For this reason I use distances within networks to construct choice sets, especially for antenatal care choice.

I define the choice set as the combination $k \in \{a, b\}$ of an antenatal care provider $a(a = 1, \ldots, N^A)$ and a child delivery provider $b(b = 1, \ldots, N^B)$. As the choice set is a combination of two choice sets, I construct them separately.

I define a woman's child delivery choice set as the four closest maternity units of level I-4 and the closest providers levels of II-1 and II-2 inside the network where the women live, plus the four closest provider of levels III-1 and the highest provider of level III-2.

Level I-4 are midwife-led maternity units and level II-1 and II-2 are intermediate obstetrician-led providers, and I assume that women will not travel to other networks in search of these level of providers. In contrast level III-1 and III-2 corresponds to those generally recognised as "national hospitals" which attracts demand not only from Lima but also from any other part of the country. It is also possible that women can travel to them inside the city.

The set of antenatal care providers available for a woman is defined as all providers inside a 5 kilometres radius from the proxy of home within the same network, plus the closest providers inside her network, either of levels I-4, II-1 and II-2, and the closest provider level III-1 inside her territorial division, and the highest provider level III-2.

Then the choice set is the set of possible combinations of antenatal care and child delivery providers. There are on average 22 antenatal care providers and 16 child delivery providers in each woman's choice set. About 90% of women chose antenatal care and child delivery providers inside this choice set.

Increasing the size of the choice sets for antenatal care and delivery is computationally costly since the number of combinations of antenatal and delivery providers is the product of the number of antenatal and delivery providers. The 10% of the sample excluded from the analysis, 24,176 observations, are those who travel greater distances especially for antenatal care. They are women with a lower number of co-morbidities (see Table A2.1 for details). This might signal either a poorer identification of women's proxy home, or strong preferences for a particular provider outside the women's constructed choice set. Of the 24,176 women who choose combination of provider out of the constructed analytical sample, 30% choose a midwife-led provider for child delivery and the rest obstetrician-led providers.

As 'provider continuity of care' is defined as women choosing the same provider for antenatal care and child delivery, the construction of this variable is straightforward.

For 'network continuity of care' first, I identify if there is a midwife-led maternity unit level I-4 or an obstetrician-led provider of level II-1 and II-2 inside the micro-network where women live[1]. If so I consider choices of antenatal care inside the micro-network and child delivery in the nearby maternity unit (i.e. in the same micro-network) as the network continuity of care,

[1]There is no micro-network that has a midwife-led provider and an obstetrician-led provider level II-1 and II-2 inside the same micro-network. There are few micro-networks where there are an Obstetrician-led provider III-1, 'national hospitals', and a midwife-led provider, in those cases the Health Ministry's guidelines assigns the population to the midwife-led maternity unit.

because this provider is the officially designed choice for child delivery inside this micro-network (Ministerio de Salud del Peru, 2012; Ministerio de Salud del Peru, 2004).

Second, and for the remaining micro-networks, I identify for a woman the closest child delivery provider, either of levels I-4, II-1, II-2 inside the same network or the closest level III-1 inside the territorial division and consider this as part of the micro-network where woman i lives. This constitutes an "augmented micro-network" with the maternity unit outside the boundaries of the official micro-network. This is based on the assumption that each maternity unit is prepared to meet the demand of the local population and coordinates with lower level providers around to identify high risk pregnancies. This assumption is likely to hold because, as explained, there are no other maternity units in the micro-network that women could be referred to. In this case I define the network continuity of care if antenatal care and child delivery are demanded inside the augmented micro-network.

I identify midwife-led continuity of care and obstetrician-led continuity of care by the type of provider attached to each micro-network, and there is only one provider with child delivery capabilities, either midwife-led or obstetrician-led unit, inside each micro-network. So there is midwife network continuity if the women choose any provider inside the micro-network for antenatal care and the provider of level I-4 inside the micro-network for child delivery, if the women choose another provider outside the micro-network for child delivery, even if this is another of level I-4, this is considered as discontinuity of care. The same criteria is applied for obstetrician-led continuity of care.

Implementing these definitions, I find that there are 29 micro-networks with at least one midwife-led maternity unit level I-4 inside their set of providers[2]. Four micro-networks with an obstetrician-led provider inside the same micro-network and 12 micro-networks where there was needed to construct an augmented micro-network using the nearby child delivery provider.

For measuring continuity of care I take into account the initial antenatal care choice; this is because women have several attendances for antenatal care and some of them choose different providers. I observe that women who choose more than one antenatal care provider move to higher level providers. I expect that my definition of network continuity is broad enough to capture movements of women in a given network.

2.3.2 Descriptive Statistics

Table 2.1 shows the tabulation of child delivery choice for continuity of care by type of provider. 58% of women live closest to a midwife-led maternity unit. If all of them choose antenatal care in any of the providers in the micro-network where they live and to give birth using the closest provider, there would be 58% of midwife-led network continuity of care.

The last four rows summarises the characteristics of actual choices. Overall 41% of women choose network continuity, of whom 15% choose midwife-led continuity of care and 26% obstetrician-led continuity of care.

Women choosing to give up network continuity of care chose mainly obstetrician-led providers. 134,360 (59%) women choose network discontinuity, 57% chose to give birth using an obstetrician-led provider and 2% in a midwife-led provider. This suggests overall that a woman who gives

[2]Among the 29 micro-networks with midwife-led maternity units there are five micro-networks with two midwife-led maternity units and one with three midwife-led maternity units, for these six micro-networks I generate a subset of lower-level providers I-1, I-2 and I-3 related to each midwife-led maternity unit by linear distances.

Table (2.1) Tabulation of women's network continuity and provider continuity of care by level of provider

	Type of maternity unit		Total
	Midwife-led	Obstetrician-led	
Women's closest child delivery provider	133,090 58%	95,858 42%	228,948 100%
NETWORK CONTINUITY			
Network continuity of care	(M,M) 34,891 15%	(O,O) 59,697 26%	94588 41%
Choice of delivery unit in case of network discontinuity	(O,M) 5,292 2%	(M,O) 129,068 57%	134,360 59%
PROVIDER CONTINUITY			
Provider continuity of care	(M,M) 16,028 7%	(O,O) 19,606 9%	35,634 16%
Choice of delivery unit in case of provider discontinuity	(O,M) 24,155 11%	(M,O) 169,159 74%	193,314 84%

Note: % is the percentage of all deliveries

up continuity of care does so for the prospect of higher structural quality at the time of child delivery. The last two rows of Table 2.1 presents similar information using provider continuity.

Figure 2.2 depicts the distribution of women according to the level of the closest maternity unit and their actual choice. This supports the thesis that overall women trade-off continuity of care and travel greater distance for higher structural quality.

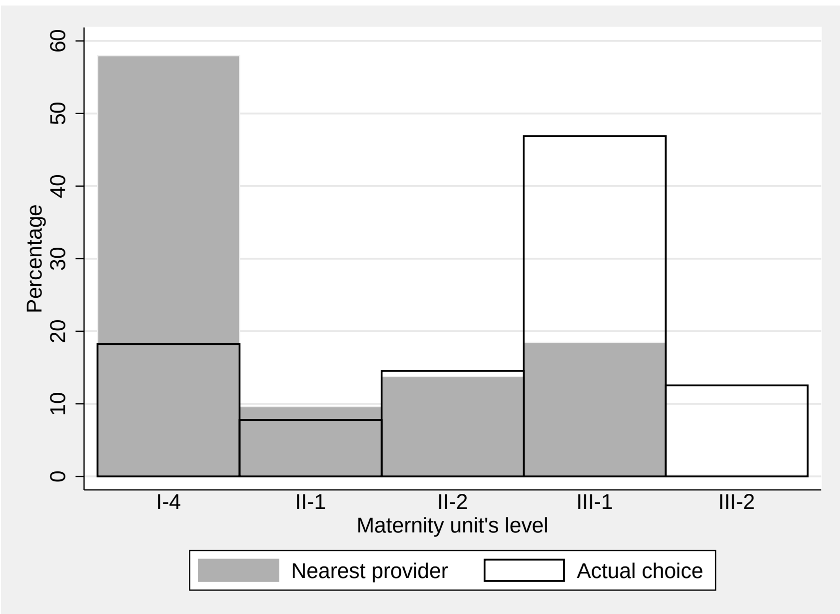

Figure (2.2) Nearest provider and actual choice of providers by levels

Figure 2.3 shows that network continuity of care either in midwife-led or obstetrician-led maternity units is decreasing over time.

Figure 2.4 shows that women choose midwife-led delivery units usually chose the nearest provider, with about 80% of women choosing a midwife-led provider, compared with less than 40% of women who chose the closest when choosing an obstetrician-led provider. This suggests women

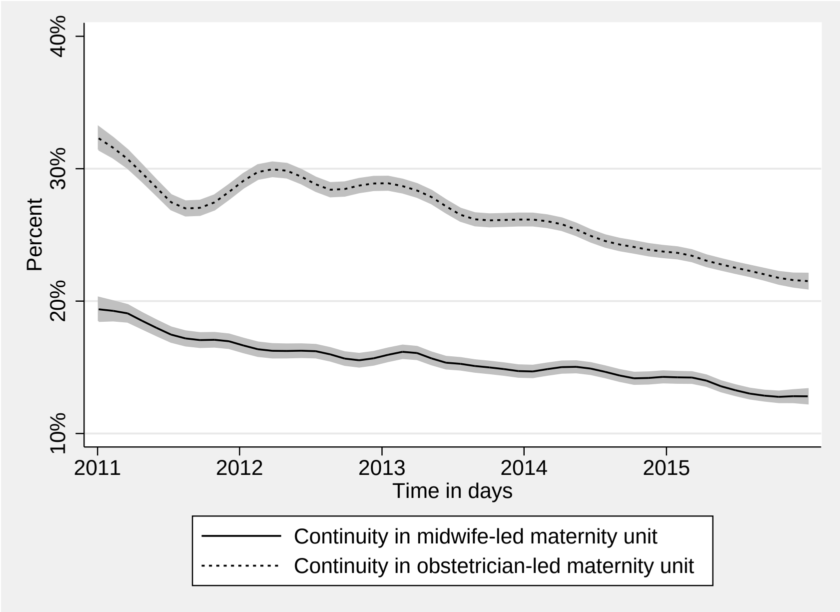

Figure (2.3) Network continuity of care in midwife-led and obstetrician-led units over time

Note: The lines plotted are the local polynomial smooth of both measures of continuity against time, the shaded regions corresponds to the 95% confidence interval

travel further for higher structural quality delivery providers. For antenatal care around 90% choose the nearest provider (see Figure A2.1 in the Appendix).

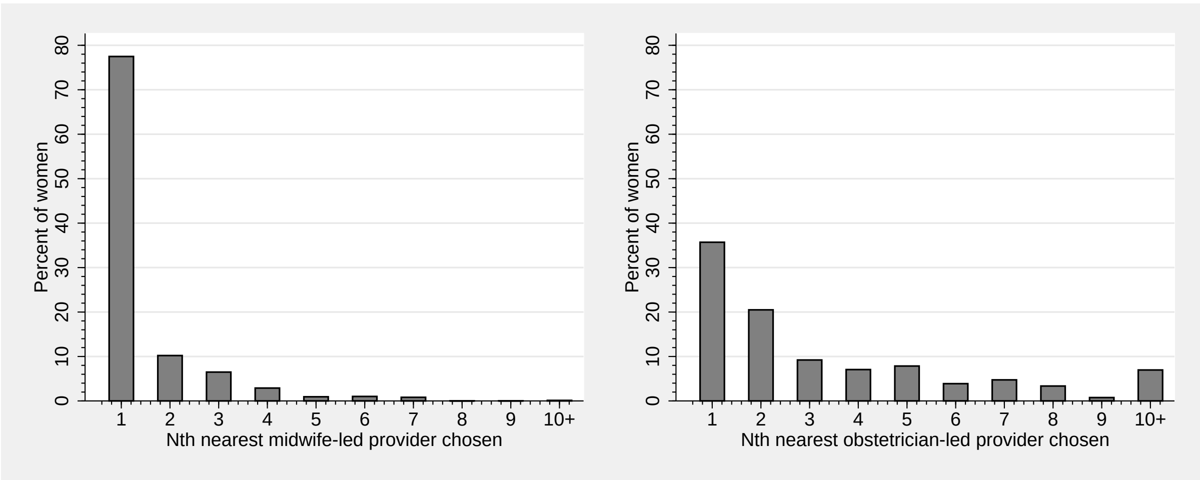

Figure (2.4) Delivery provider chosen for women choosing midwife-led and obstetrician-led providers

Table 2.2 presents the descriptive statistics for distances travelled for child delivery and antenatal care by type of delivery provider. Overall women travel further for giving birth in obstetrician-led providers (5.4km) than for giving birth on midwife-led providers (1.6km). The distances travelled for antenatal care are considerably less 0.2km for choosing a provider in a midwife-led network and 0.45km for choosing a provider in an obstetrician-led network, these suggest that women choose antenatal care locally.

Table 2.3 presents the descriptive statistics of women's characteristics of the pregnancy (pre-delivery) period which are used in the main regression model. Age is included in five categories, Table (2.2) Descriptive statistics of distances

	Mean, SD
Distances	
Distance (in Km) travelled for child delivery	4.809
	(5.356)
Distance (in Km) travelled for delivery (midwife-led unit)	1.589
	(2.139)
Distance (in Km) travelled for delivery (obstetrician-led unit)	5.498
	(5.584)
Distance (in Km) travelled for antenatal care	0.394
	(1.522)
Distance (in Km) travelled for antenatal (midwife-led network)	0.205
	(1.015)
Distance (in Km) travelled for antenatal (obstetrician-led network)	0.446
	(1.667)
Observations	228948

Note: Standard deviations for distances in parenthesis.

the youngest group have 26% of women who are less than 21 years, and the oldest group have 10% of women with 35 years and more. 7% of women have more than one delivery, during the period 2011-2015, the average length of stay in hospitalization during the pregnancy period and before the delivery is about 0.3 days. The rest of dummy variables are maternal co-morbidities recorded during the pregnancy period.

2.4 Results

Table 2.4 presents conditional logit regression results for the simple model specified in equation 2.13. Column (1) showing the coefficient and standard errors regression results for my broad definition of network continuity of care, while column (2) shows the coefficients and standard error regression results for my definition of provider continuity of care.

In this model I do not make a distinction between midwife-led and obstetrician-led continuity of care; I include distances but not their interaction with patient characteristics. The first coefficient in column 1 (1.308) and in column 2 (1.584) show that women value network continuity of care and provider continuity of care. The second coefficient in column 1 (2.431) and in column 2 (2.291) show that obstetrician-led providers are preferred for child delivery. Likewise, the following pair of coefficients (1.210) and (0.467) show that obstetrician-led providers are preferred for antenatal care. Distance, as expected, have negative marginal utility.

Next, in Table 2.5, I present results from model (2.14) with no distance interactions which allows the value of continuity to depend on whether it is in midwife-led or obstetrician-led units. The first column corresponds to the network continuity of care. The first four coefficients estimate utilities for midwife-led continuity of care ($\beta_M = 2.340$), obstetrician-led continuity of care ($\beta_O = 0.952$), high structural quality (obstetrician-led) provider for child delivery ($\beta_{q_{chd}} = 3.283$) and high structural quality (obstetrician-led) provider for antenatal care ($\beta_{q_{anc}} = 1.390$).

Table 2.6 presents the results from model (2.14) with distance interactions with women's co-morbidities. The first four coefficients are interpreted as in Table 2.5 and have similar magnitudes.

The distance coefficients have the expected negative sign, with the marginal disutility of distance travelled for child delivery smaller than that for antenatal care are similar to those in Tables (2.4) and (2.5).

In general higher risk women are willing to travel further, for example for younger and older

Table (2.3) Descriptive statistics of women's characteristics

	Mean, SD
Womens's characteristics of the pregnancy period	
Age 1 (<21 years)	0.258
	(0.438)
Age 2 (21-25 years)	0.276
	(0.447)
Age 3 (26-30 years)	0.215
	(0.410)
Age 4 (31-35 years)	0.148
	(0.355)
Age 5 (>35 years)	0.103
	(0.304)
Delivery before	0.068
	(0.252)
Length of stay (in days) before delivery	0.324
	(1.664)
Gestational hypertension	0.040
	(0.196)
Pre-eclampsia	0.0596
	(0.237)
Haemorrhage in early pregnancy	0.022
	(0.147)
Diabetes mellitus in pregnancy	0.018
	(0.131)
Maternal care for other conditions	0.038
	(0.192)
Multiple gestation	0.007
	(0.081)
Known or suspected malpresentation of fetus	0.043
	(0.203)
Known or suspected disproportion	0.045
	(0.207)
Known or suspected abnormality of pelvic organs	0.118
	(0.322)
Known or suspected fetal abnormality and damage	0.005
	(0.071)
Known or suspected fetal problems	0.054
	(0.226)
Polyhidrammios	0.0098
	(0.099)
Disorders of amniotic fluid and membranes	0.017
	(0.128)
Premature rupture of membranes	0.014
	(0.116)
Placental disorders	0.024
	(0.154)
Placenta praevia	0.010
	(0.099)
False labour	0.071
	(0.257)
Prolonged pregnancy	0.010
	(0.100)
Infectious and parasitic diseases classifiable elsewhere	0.015
	(0.123)
Observations	228948

Note: All variables, with the exception of length of stay measured in days, are dummy variables. Standard deviations for women's characteristics in parenthesis.

Table (2.4) Estimated marginal utilities (simple model)

	(1) Network continuity		(2) Provider continuity	
	β	SE	β	SE
Continuity of care				
Network continuity of care (β_C)	1.308***	(0.007)		
Provider continuity of care (β_C)			1.584***	(0.011)
Structural quality of providers				
High structural quality provider for child delivery ($\beta_{q_{chd}}$)	2.431***	(0.008)	2.291***	(0.008)
High structural quality provider for antenatal care ($\beta_{q_{anc}}$)	1.210***	(0.013)	0.467***	(0.016)
Distances				
Distance (in Km) travelled for delivery ($\beta_{D^{chd}}$)	−0.189***	(0.001)	−0.228***	(0.001)
Distance (in Km) travelled for antenatal care ($\beta_{D^{anc}}$)	−2.007***	(0.009)	−1.961***	(0.009)
Women	228,948		228,948	
Observations	43,914,862		43,914,862	
Pseudo R^2	0.50		0.49	
Log Likelihood	−593441.62		−600860.27	
AIC	1186893.24		1201730.54	
BIC	1186971.23		1201808.53	

Note: Conditional logit model for equation (2.13) with no interactions of distance with women's characteristics. Dependent variable: utility from choices; the coefficients represent marginal utilities. The first column presents the regression results for network continuity of care, while the second column regression results for provider continuity of care. High structural quality is a dummy variable if women chooses obstetrician-led providers rather than midwife-led providers, either, for child delivery or antenatal care. Robust standard errors in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table (2.5) Estimated marginal utilities (base model)

	(1) Est.		(2) SE	
	β	SE	β	SE
Continuity of care				
Network continuity in midwife-led unit (β_M)	2.340***	(0.016)		
Network continuity in obstetrician-led (β_O)	0.952***	(0.008)		
Provider continuity in midwife-led unit (β_M)			1.571***	(0.013)
Provider continuity in obstetrician-led unit (β_O)			1.612***	(0.019)
Structural quality of providers				
High structural quality provider for child delivery ($\beta_{q_{chd}}$)	3.283***	(0.015)	2.286***	(0.008)
High structural quality provider for antenatal care ($\beta_{q_{anc}}$)	1.309***	(0.013)	0.445***	(0.020)
Distances				
Distance (in Km) travelled for delivery ($\beta_{D_{chd}}$)	−0.192***	(0.001)	−0.228***	(0.001)
Distance (in Km) travelled for antenatal care ($\beta_{D_{chd}}$)	−1.998***	(0.009)	−1.961***	(0.009)
Women	228,948		228,948	
Observations	43,914,862		43,914,862	
Pseudo R^2	0.50		0.49	
LR chi2	217447.25		214396.40	
Prob > chi2	0.00		0.00	
Log Likelihood	−589423.04		−600858.39	
AIC	1178858.09		1201728.78	
BIC	1178951.67		1201822.36	

Note: Conditional logit model for equation (2.14) with no interactions of distance with women's characteristics. Dependent variable: utility function choices; the coefficients represent marginal utilities. Column (1) presents the regression results for network continuity of care, while column (2) has regression results for provider continuity of care. Robust standard errors in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table (2.6) Estimated marginal utilities (base model) with distance interacted woman's characteristics with structural quality for child delivery

	(1) Est.		(2) SE	
	β	SE	β	SE
Continuity of care				
Network continuity in midwife-led unit (β_M)	2.303***	(0.016)		
Network continuity in obstetrician-led (β_O)	0.942***	(0.008)		
Provider continuity in midwife-led unit (β_M)			1.537***	(0.013)
Provider continuity in obstetrician-led unit (β_O)			1.631***	(0.019)
Structural quality of providers				
High structural quality provider for child delivery ($\beta_{q_{chd}}$)	3.295***	(0.015)	2.308***	(0.008)
High structural quality provider for antenatal care ($\beta_{q_{anc}}$)	1.327***	(0.013)	0.446***	(0.020)
Distances				
Distance (in Km) travelled for delivery ($\beta_{D^{chd}}$)	−0.263***	(0.004)	−0.310***	(0.004)
Distance (in Km) travelled for antenatal care ($\beta_{D^{anc}}$)	−1.683***	(0.029)	−1.648***	(0.028)
Patient's characteristics interacted with child delivery distance				
Age 1 (< 21 years)	0.024***	(0.002)	0.028***	(0.002)
Age 2 (21 - 25 years)	0.004**	(0.002)	0.004*	(0.002)
Age 3 (26 - 30 years)	Ref.		Ref.	
Age 4 (31 - 35 years)	0.002	(0.002)	0.003	(0.003)
Age 5 (> 35 years)	0.014***	(0.002)	0.019***	(0.003)
Delivery before=1	−0.038***	(0.003)	−0.047***	(0.003)
Length of stay (in days) before delivery	0.007***	(0.000)	0.008***	(0.000)
Gestational hypertension	0.034***	(0.003)	0.046***	(0.004)
Pre-eclampsia	0.006**	(0.003)	0.008**	(0.003)
Haemorrhage in early pregnancy	−0.009**	(0.005)	−0.016***	(0.006)
Diabetes mellitus in pregnancy	0.011**	(0.005)	0.013**	(0.006)
Maternal care for other conditions	−0.010***	(0.003)	−0.003	(0.004)
Multiple gestation	0.067***	(0.006)	0.080***	(0.007)
Known or suspected malpresentation of foetus	−0.013***	(0.003)	−0.022***	(0.004)
Known or suspected disproportion	−0.000	(0.003)	−0.001	(0.004)
Known or suspected abnormality of pelvic organs	0.027***	(0.002)	0.030***	(0.002)
Known or suspected foetal abnormality and damage	0.080***	(0.007)	0.092***	(0.008)
Known or suspected foetal problems	0.000	(0.003)	−0.009***	(0.003)
Polyhidrammios	0.009*	(0.005)	0.003	(0.007)
Disorders of amniotic fluid and membranes	−0.005	(0.005)	−0.015**	(0.006)
Premature rupture of membranes	0.024***	(0.006)	0.021***	(0.007)
Placental disorders	0.047***	(0.003)	0.059***	(0.004)
Placenta praevia	0.017***	(0.005)	0.021***	(0.006)
False labour	0.075***	(0.002)	0.084***	(0.002)
Prolonged pregnancy	0.009	(0.006)	0.010	(0.007)
Infectious and parasitic diseases classifiable elsewhere	−0.003	(0.004)	0.014***	(0.005)
January	Ref.		Ref.	
February	−0.001	(0.004)	−0.002	(0.004)
March	−0.003	(0.003)	−0.003	(0.004)
April	−0.004	(0.004)	−0.006	(0.004)
May	0.004	(0.003)	0.004	(0.004)
June	−0.002	(0.003)	−0.003	(0.004)
July	0.014***	(0.003)	0.018***	(0.004)
August	0.003	(0.003)	0.005	(0.004)
September	0.007**	(0.003)	0.009**	(0.004)
October	0.008**	(0.003)	0.010**	(0.004)
November	0.013***	(0.003)	0.015***	(0.004)
December	0.009***	(0.003)	0.011**	(0.004)
2011	Ref.		Ref.	
2012	0.012***	(0.003)	0.012***	(0.003)
2013	0.037***	(0.002)	0.042***	(0.003)
2014	0.053***	(0.002)	0.061***	(0.003)
2015	0.074***	(0.002)	0.090***	(0.003)
Patient's characteristics interacted with antenatal care distance (omited)				
Women	228,948		228,948	
Observations	43,914,862		43,914,862	
Pseudo R^2	0.51		0.50	
LR chi2	216110.20		214587.16	
Prob > chi2	0.00		0.00	
Log Likelihood	−583248.81		−593945.31	
AIC	1166629.62		1188022.62	
BIC	1167659.07		1189052.08	

Note: Conditional logit model for equation (2.14) with interactions of distance with women's characteristics. Dependent variable: utility from choices; the coefficients represent marginal utilities. The first column presents the regression results for network continuity of care, while the second column regression results for provider continuity of care. Robust standard errors in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

women, women with greater length of stay in hospitalisation, or women with gestational hypertension, pre-eclampsia and diabetes, among others. There are some exceptions with negative coefficients, such as previous delivery which signals that women with previous experience of delivery travel less, and for women with haemorrhage in early pregnancy or malpresentation of fetus, which suggest that those women will prefer to travel less, plausibly due to potential emergency.

Women are willing to travel more at the end of the year. Possibly due to the weather there is more comfort in travelling during months with low temperature but also the transport system is more congested in the city compared to summer when there is school holiday (January to March), so no clear pattern can be inferred for these monthly dummies. Removing the seasonal effect, although not crucial, increase the precision in the point estimates of the coefficients of interest.

Finally note that women became more willing to travel over time: the coefficients on the year dummies are positive and increasing from 2012 to 2015, this signalling an increase willingness to travel. There are two possible explanations for this. First changes in the composition of women over time, i.e. if there are more sicker women over time they might choose higher level providers due to their pregnancy risk. Second there may be secular trends in preferences in favour of obstetrician-led providers.

Table A2.2, in the Appendix, compares women giving birth in 2011 and in 2015. On average over time, women are younger (specifically women less than 19 years old), have less previous deliveries, less length of stay in hospitalization during the pregnancy period, less pre-eclampsia, haemorrhage, suspected malpresentation of foetus, disproportion or pelvic abnormalities, placenta praevia and infections and parasitic diseases. However there are six co-morbidities that was increased: diabetes, foetal problems, polyhidramnios, disorders of amniotic fluid and membranes, premature rupture of membranes, and placental disorders. Seven other comorbidities did not change. In general, there are not clear worsening in women health conditions that can affect women choice due to health status. It seems plausibly therefore that the changes in willingness to travel are due to changes in women's preferences.

The estimated utility function is unique only up to a proportional transformation (Train, 2003). We can express the utility from structural quality on continuity in terms of the additional distance a woman would be willing to travel to have care with that characteristic as $WTT_{characteristic} = -\beta_{characteristic}/\beta_{distance}$

Table 2.7 estimates the willingness to travel for continuity in each type of provider and for high structural quality in obstetrician-led units for child delivery and for antenatal care using results for model 2.14 presented in Table 2.6.

The willingness to travel (in km) estimated for choosing combination $\{O, O\}$ is the sum of WTT for network continuity in obstetrician-led unit (3.587) plus hight structural quality for child delivery (12.552)) plus high structural quality for antenatal care (5.056) equals to 21.195. This value is recorded in the first row and last column of Table 2.8. For combination $\{M, M\} = 8.770$ this corresponds to network continuity in midwife-led provider alone, this is because for structural quality choice for, both, child delivery and antenatal care, the midwife-led provider is the base case. For combination $\{M, O\} = 12.552$ this corresponds to choosing hight structural quality for child delivery alone. Finally, for combination $\{O, M\} = 5.056$, this is the value of choosing hight structural quality provider for antenatal care. So the willingness to travel by combination of choices are $\{O, O\} = 21.2$, $\{M, M\} = 8.8$, $\{M, O\} = 12.6$, and $\{O, M\} = 5.1$ which are presented in the last column of Table 2.8.

Table (2.7) Estimated willingness to travel base model

	(1) Est.		(2) Est.	
	β	SE	β	SE
Continuity of care				
WTT Network continuity in midwife-led unit	8.770***	(0.138)		
WTT Network continuity in obstetrician-led unit	3.587***	(0.062)		
WTT Provider continuity in midwife-led unit			4.464***	(0.084)
WTT Provider continuity in obstetrician-led unit			5.226***	(0.098)
Structural quality of providers				
WTT High structural quality provider for child delivery	12.552***	(0.180)	7.455***	(0.107)
WTT High structural quality provider for antenatal care	5.056***	(0.086)	1.440***	(0.067)

Note: The willingness to travel is estimated by the negative of coefficients on quality measures divided by the coefficient on distance travelled for child delivery estimated in Table 2.6. For example the first coefficient of this table 8.770 is estimated as $-\beta_M/\beta_{D^{chd}}$=-(2.303/-0.263) of Table 2.6. Standard errors estimated by the delta method in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

From Table 2.1 133,090 women live close to a midwife-led provider, from them 34,891 (26%) choose combination $\{M, M\}$, network continuity in midwife-led providers, the difference 98,199 choose combination $\{M, O\}$[3].

The equivalent reduction in distance (in km) for midwife-led continuity of care for them is $\{M, O\} - \{M, M\} = 3.8$. This is a dramatic change because on average women are travelling 5.5km to give birth in obstetrician-led providers, where the reduction in distance required to distances in the margins to switch the demand from obstetrician-led maternity units for midwife-led maternity units is about a 70% reduction in the distance travelled. Clearly only women that are close enough to midwife-led providers have an incentive to demand its services for delivery as well as antenatal care.

On the other hand women are willing to travel 21.2km for obstetrician-led continuity $\{O, O\}$. To encourage these women to choose combination $\{M, M\}$ or even $\{M, O\}$ requires an equivalent reduction in distance of 12.4km or 8.6km respectively. The women who prefer obstetrician-led continuity of care are very unlikely to switch to any other choice.

5,292 out of 228,948 choose combination $\{O, M\}$: discontinuity of care and choice of midwife-led provider for child delivery. This combination only represents 2.3% of choices and are an exception. These are women who first choose an obstetrician-led provider and then revise their valuation of quality of obstetrician-led providers for child delivery downwards, or require delivery urgently and opt for midwife delivery because it is closer.

In general, I find similar results for network continuity of care and for provider continuity of care. However the Bayesian information criterion BIC signals that, on statistical grounds, network continuity of care performs better. It's also more realistic in representing how providers operate in Lima.

Table 2.8 compares the utilities and willingness to travel for combination of choices for network continuity using the results from Tables 2.4, 2.5 and 2.6. Using the results for network continuity estimated in the simple model (first column, Table 2.4) the utilities and willingness to travel for all possible combinations are estimated as follow: utility for choosing combination $\{O, O\}$ is $\beta_C + \beta_{q_{chd}} + \beta_{q_{anc}} = 4.949$, this is the value of continuity of care, which are assumed to be equal for midwife-led providers and obstetrician-led providers in this simple model, plus

[3] More precisely, 98,199 women are choosing discontinuity of care, including combination $\{M, O\}$ and few cases of combination $\{M, M\}$, women who choose a midwife-led provider for child delivery in another different network, as there are very few cases these do not affect the estimation.

the utilities for choosing high structural quality providers for antenatal care and child delivery. Combination $\{M, M\}$ is assumed to be equal to $\beta_C = 1.308$, the common continuity of care utility. Combination $\{M, O\}$ is equal to choose obstetrician-led provider for child delivery, and combination $\{M, O\}$ equal to choose obstetrician-led provider for antenatal care.

Table (2.8) Utilities and willingness to travel (WTT) by combination of choices

	Simple model		Base model		Base model (cov.)	
	Utility	WTT	Utility	WTT	Utility	WTT
Obstetrician continuity of care (O,O)	4.949	26.218	5.544	28.855	5.564	21.195
	(0.017)	(0.015)	(0.021)	(0.175)	(0.021)	(0.304)
Midwife-led continuity of care (M,M)	1.308	6.928	2.340	12.177	2.303	8.771
	(0.007)	(0.058)	(0.016)	(0.106)	(0.016)	(0.138)
Discontinuity (M,O)	2.431	12.879	3.283	17.089	3.295	12.552
	(0.008)	(0.061)	(0.015)	(0.101)	(0.015)	(0.180)
Discontinuity (O,M)	1.210	6.441	1.309	6.812	1.327	5.056
	(0.013)	(0.076)	(0.013)	(0.076)	(0.013)	(0.086)

Note: All estimations are significant *** p<0.01. The willingness to travel for each combination of choices are estimated by dividing the estimated utilities by the negative of the coefficient on distance to child delivery providers. For example utility for choosing combination $\{O, O\}$ is $\beta_C + \beta_{q_{chd}} + \beta_{q_{anc}}$ and this is divided by $-\beta_{D^{chd}}$. For the simple model (columns 1 and 2) I use the results in Table 2.4, for the base model (columns 3 and 4) the Table 2.5, and for the base model with covariates (columns 5 and 6) the Table 2.6, in all of them the estimation for network continuity of care.

Using coefficients from Table 2.5 the utilities for choice combinations are: utility for choosing combination $\{O, O\}$ is $\beta_O + \beta_{q_{chd}} + \beta_{q_{anc}} = 5.544$, this is because women choosing continuity in an obstetrician-led provider adds the utilities of structural higher quality in both choices plus the utility of continuity of care in this type of provider. For combination $\{M, M\}$ this is for choosing midwife-led provider continuity the utility is identical to $\beta_M = 2.340$, this is because the structural quality in midwife-led providers for antenatal care and child delivery act as reference base in the estimation.

The utility for choosing combination $\{M, O\}$ is $\beta_{q_{chd}} = 3.283$. This is the utility for women who choose antenatal care in midwife-led network, and choosing an obstetrician-led provider for child delivery [4]. The utility for choosing combination $\{O, M\} = \beta_{q_{anc}} = 1.309$, this combination has the lowest utility.

Comparing the combinations $\{M, M\}$ and $\{M, O\}$, I find that although women value midwife-led providers and midwife-led continuity of care, the utility of choosing midwife-led continuity $\{M, M\}$ is 2.340 and is less than the utility of discontinuity from higher structural quality provider for child delivery (combination $\{M, O\} = 3.283$). Women will prefer to forego midwife-led network continuity of care for the prospect of better structural quality in obstetrician-led providers for giving birth and this is the main finding of this chapter, unless the additional distance cost is greater than 3.283-2.340. The utility of distance to child delivery providers $\beta_{d^{chd}} = -0.192$ and to antenatal care providers $\beta_{d^{anc}} = -1.998$ are very close to the corresponding coefficients estimated in Table 2.4. The second column of Table 2.5 presents results for provider continuity and the main findings remain unchanged.

The results for the model with interactions of distances with women's characteristics is constructed likewise. In all three models women's willingness to travel is higher for combination $\{O, O\}$ followed by combination $\{M, O\}$ followed by combination $\{M, M\}$ and lastly by

[4]In the estimation women only receive the marginal utility for choosing high structural (obstetrician-led) quality provider at the time of child delivery, but no marginal utility for choosing the midwife-led provider for antenatal care, again because the structural quality of midwife-led provider is the implicit reference base in the estimation.

combination$\{O, M\}$, which confirms that women will prefer travelling further to give birth in an obstetrician-led provider rather than choosing continuity of care in midwife-led providers.

2.4.1 Sensitivity analysis

I test if results are sensitive to different specifications of the disutility of distance in the basic model. Table 2.9 presents in column (1) results for linear specification, column (2) squared, column (3) cubic, column (4) quartic and column (5) the hyperbolic sine. This last one approximates the logarithmic function when there are values of distance equal to zero (Zhang et al., 2000).

In general these show that as the distance polynomials increases the coefficients on continuity of care decreases, the coefficients on quality choice for child delivery and antenatal care increase.

Table (2.9) Estimated marginal utilities: non linear distance costs

	(1)	(2)	(3)	(4)	(5)
Continuity of care					
Network continuity in midwife-led unit	2.340***	2.137***	1.965***	1.924***	1.459***
	(0.016)	(0.016)	(0.016)	(0.017)	(0.017)
Network continuity in obstetrician-led	0.952***	0.738***	0.649***	0.657***	0.701***
	(0.008)	(0.008)	(0.009)	(0.009)	(0.009)
Structural quality of providers					
High structural quality provider for child delivery	3.283***	3.341***	3.355***	3.356***	3.280***
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
High structural quality provider for antenatal care	1.309***	1.426***	1.625***	1.650***	1.909***
	(0.013)	(0.014)	(0.017)	(0.018)	(0.016)
Distances					
Distance (in Km) travelled for delivery	−0.192***	−0.302***	−0.404***	−0.439***	
	(0.001)	(0.001)	(0.002)	(0.004)	
Distance (in Km) travelled for delivery squared		0.005***	0.012***	0.016***	
		(0.000)	(0.000)	(0.000)	
Distance (in Km) travelled for delivery cubic			−0.000***	−0.000***	
			(0.000)	(0.000)	
Distance (in Km) travelled for delivery quartic				0.000***	
				(0.000)	
Distance (in Km) travelled for delivery hyperbolic sine					−1.288***
					(0.005)
Distance (in Km) travelled for antenatal care	−1.998***	−2.172***	−3.010***	−3.402***	
	(0.009)	(0.008)	(0.030)	(0.032)	
Distance (in Km) travelled for antenatal care squared		0.039***	0.322***	0.490***	
		(0.000)	(0.011)	(0.014)	
Distance (in Km) travelled for antenatal care cubic			−0.009***	−0.023***	
			(0.001)	(0.001)	
Distance (in Km) travelled for antenatal care quartic				0.000***	
				(0.000)	
Distance (in Km) travelled for antenatal care hyperbolic sine					−3.375***
					(0.008)
Observations	43,914,862	43,914,862	43,914,862	43,914,862	43,914,862
Women	228,948	228,948	228,948	228,948	228,948
Pseudo R^2	0.50	0.52	0.55	0.56	0.56
LR chi2	217447.25	279301.90	398187.21	434774.75	363832.24
Prob > chi2	0.00	0.00	0.00	0.00	0.00
Log Likelihood	−589423.04	−568148.15	−527102.24	−515524.16	−517489.13
AIC	1178858.09	1136312.31	1054224.48	1031072.32	1034990.27
BIC	1178951.67	1136437.09	1054380.46	1031259.49	1035083.85

Note: Robust standard errors in parenthesis. * p<0.1, ** p<0.05, *** p<0.01. Dependent variable utility function from choices, the coefficients represent marginal utilities. The columns show distance specifications: Column (1) linear, column (2) quadratic, column (3) cubic, column (4) quartic and column (5) hyperbolic sine distances.

Table 2.10 presents the estimation of willingness to travel for non linear distance costs presented in Table 2.9 using the average distance travelled for child delivery. The willingness to travel decreases for all combination as the polynomial of distance increases up to the cubic form, there is no much difference with the quartic polynomial signalling that after that it seems that there is no further reduction in willingness to travel. Although the magnitud of the estimated willingness to travel varies, the order of preferences of different combinations do not.

Overall these changes reduce the willingness to travel for continuity of care and to access obstetrician-led providers for child delivery. However none of them affect the overall significance or direction of my findings.

Table (2.10) Willingness to travel for combination of choices: non linear distance costs

	Linear	Squared	Cubic	Quartic	Hyperbolic sine
Obstetrician continuity of care (O,O)	28.855	21.431	18.818	18.606	21.981
	(0.175)	(0.124)	(0.119)	(0.122)	(0.116)
Midwife-led continuity of care (M,M)	12.177	8.321	6.568	6.322	5.447
	(0.106)	(0.075)	(0.069)	(0.070)	(0.072)
Discontinuity (M,O)	17.089	13.006	11.218	11.026	12.241
	(0.101)	(0.072)	(0.066)	(0.066)	(0.062)
Discontinuity (O,M)	6.812	5.553	5.431	5.422	7.125
	(0.076)	(0.058)	(0.060)	(0.064)	(0.066)

Note: Standard errors estimated using the delta method in parenthesis. All estimations are significant *** p<0.01. The willingness in to travel in column (1) for each combination of choices are estimated dividing the estimated utilities by the negative of the partial derivative of utility on distance to child delivery providers. For example utility for choosing combination $\{O, O\}$ is $\beta_C + \beta_{q_{chd}} + \beta_{q_{anc}}$ and this is divided by $-\beta_{D^{chd}}$, the partial derivative on distance in the linear case, for the second column the utility for choosing the combination is divided by $-[\beta_{D^{chd}} + 2\beta_{D^{chd}} D^{chd}]$ and so on for the following distance transformations.

I also fit the mixed logit model to relax the independence of irrelevant alternatives assumption implied by conditional logit (Train, 2003). Specifically it is assumed that network continuity of care in midwife-led and network continuity of care in obstetrician-led units have normally distributed coefficients, and on the other hand high structural quality for antenatal care and high structural quality for child delivery have fixed coefficients. This mixed logit model examines the heterogeneity in women's taste for continuity of care pay-off.

Table 2.11 compares the results for the base model, with no interaction of distances with women's characteristics. Column (1) conditional logit, and column (2) mixed logit model. It shows that the mixed logit model estimates lower coefficients for network continuity of care, specially for network continuity of care in midwife-led units, greater coefficients for high structural quality provider for child delivery, slightly lower coefficient for high structural quality provider for antenatal care and slightly more negative coefficients for distances. Together, the coefficients estimated by mixed logit imply even a lower willingness to travel for midwife-led continuity of care estimated compared with the willingness to travel choosing discontinuity of care and obstetrician-led provider for child delivery. However, the main direction of my findings do not change.

Overall I find that the pattern of my results is robust to changes in method of estimation and changes in model specification.

2.5 Concluding remarks

The distinctive contribution of this chapter to the literature is the consideration of different dimensions of quality when analysing the choice of healthcare provider. Women do not only travel further for higher structural quality at delivery but also are willing to give up process quality measured as continuity of care.

Over the five years of the study continuity of care has fallen. Since choice of providers is influenced by distance one possible policy to encourage continuity in midwife-led providers is to reduce distance costs by building more midwife-led units. In the next chapter I examine the effects of this policy.

My methods are applicable in other health systems where women have choices of different

Table (2.11) Estimated marginal utilities: conditional logit and mixed logit

	(1) Conditional logit		(2) Mixed logit	
	β	SE	β	SE
Continuity of care				
Network continuity in midwife-led unit (β_M	2.340***	(0.016)	1.176***	(0.027)
Network continuity in obstetrician-led (β_O	0.952***	(0.008)	0.698***	(0.018)
Structural quality of providers				
High structural quality provider for child delivery ($\beta_{q_{chd}}$	3.283***	(0.015)	3.660***	(0.017)
High structural quality provider for antenatal care ($\beta_{q_{anc}}$	1.309***	(0.013)	1.188***	(0.015)
Distances				
Distance (in Km) travelled for delivery (β_{Dchd})	−0.192***	(0.001)	−0.233***	(0.001)
Distance (in Km) travelled for antenatal care (β_{Danc})	−1.998***	(0.009)	−2.117***	(0.009)
Observations	43,914,862		43,914,862	
Women	228,948		228,948	
LR chi2	217447.25		136085.87	
Prob > chi2	0.00		0.00	
Log Likelihood	−589423.04		−579909.26	
AIC	1178858.09		1159834.53	
BIC	1178951.67		1159959.31	

Note: Dependent variable utility function from choices, the coefficients represent marginal utilities. Conditional logit and mixed logit model regression results for equation (2.14) using network continuity of care and excluding interaction of distances with patients characteristics. Robust standard errors in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

providers with different structural quality and can choose different providers for antenatal care and delivery so that continuity considerations can affect their choices.

A possible limitation is measurement errors due to imputed distances. As explained in the introduction of this thesis, given the absence of data on home address, I compute distances using the facility which was most frequently used by women for non-antenatal and child delivery care as proxy of their home address. This introduces potential measurement errors in my estimation. However, for identifying the most used provider as a home address proxy I use information on 2,615,999 additional records not related to antenatal care or child delivery, which makes an average of nine observations per women. The assumption that women use local facilities near their homes for other types of health services such dentistry and primary care seems plausible.

I use the addresses of 366 providers as proxies, which makes up the same number of geographical coordinates distributed in Lima. By contrast there are only 158 postal codes in Lima (Ministerio de Transportes y Comunicaciones del Peru, 2011). I therefore assume that errors in the distance measure are unlikely to be correlated with the types of antenatal or delivery providers.

Serious health problems, real or perceived, can lead to women demanding services in higher level providers, as already shown in this study. To address this I exclude observations for non-antenatal and child delivery care where the providers where used for emergency care, and in doing so, I argue that it is less likely that a woman can demand a primary provider far from home.

A second possible caveat is that although the women are insured they may still incur out of pocket costs for medicines and these may vary by type of provider used. This may affect the interpretation of the estimated coefficients on structural quality as they could also reflect systematic variation in out of pocket costs as well as the effect of quality on utility.

The simple theory model is not capable of explaining why women might choose an obstetrician-led provider for antenatal care but a midwife-led provider for delivery $\{O, M\}$. Only about 10% of women chose this combination but in future work I plan to extend the theory model to include this case by allowing for the possibility that women may revise their belief about quality after experiencing a provider or may require admission for delivery more urgently than they anticipated when planning their mix of providers.

I also plan to investigate if results are sensitive to the specification of the choice set, for example by using purely distance based choice sets.

Appendix A: Additional tables and figures

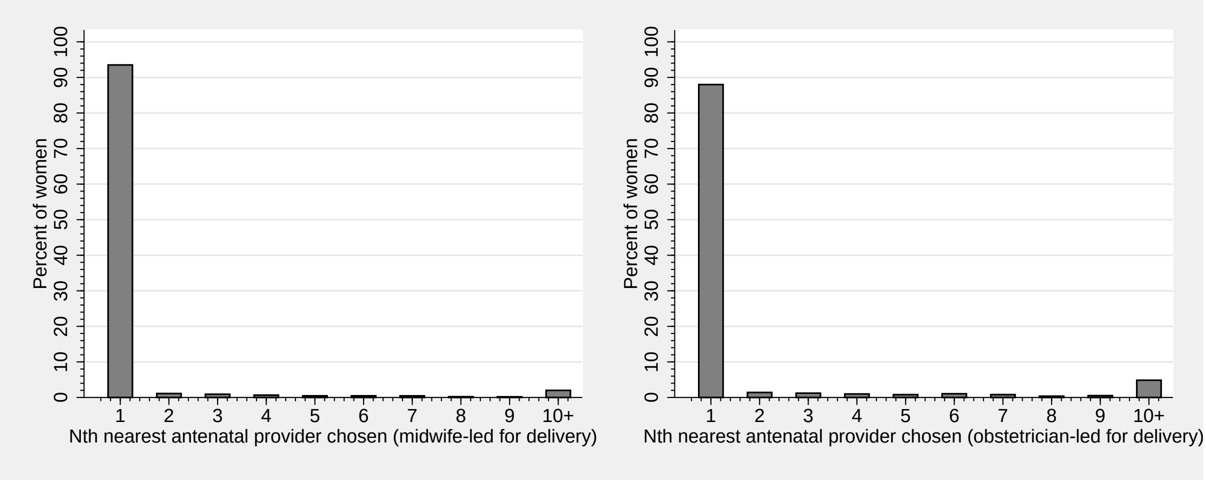

Figure (A2.1) Nearest antenatal care provider chosen for women choosing midwife-led and obstetrician-led provider for delivery

Table (A2.1) Descriptive statistics analytical sample and dropped observations

	All	Analitical sample	Out choice set	Diff. means
Distances				
Distance (in Km) travelled for child delivery	5.000	4.809	6.810	−2.001***
	(5.880)	(5.356)	(9.309)	
Dist. (in Km) travelled for delivery (midwife-led unit)	1.932	1.589	3.882	−2.234***
	(3.550)	(2.139)	(7.248)	
Dist. (in Km) travelled for delivery (obstetrician-led unit)	5.707	5.498	8.044	−2.546***
	(6.079)	(5.584)	(9.776)	
Distance (in Km) travelled for antenatal care	0.927	0.394	5.959	−5.565***
	(3.419)	(1.522)	(8.502)	
Dist. (in Km) travelled for antenatal (midwife-led unit)	0.675	0.205	3.246	−3.040***
	(3.244)	(1.015)	(7.396)	
Dist. (in Km) travelled for antenatal (obstetrician-led unit)	0.984	0.446	7.003	−6.558***
	(3.455)	(1.667)	(8.650)	
Womens's characteristics of the pregnancy period				
Age 1 (<21 years)	0.2582	0.2583	0.2572	0.0011
	(0.438)	(0.438)	(0.437)	
Age 2 (21-25 years)	0.2775	0.2763	0.2886	−0.0123***
	(0.448)	(0.447)	(0.453)	
Age 3 (26-30 years)	0.2146	0.2145	0.2164	−0.0019
	(0.411)	(0.410)	(0.412)	
Age 4 (31-35 years)	0.1477	0.1481	0.1444	0.0036
	(0.355)	(0.355)	(0.352)	
Age 5 (>35 years)	0.1020	0.1029	0.0934	0.0095***
	(0.303)	(0.304)	(0.291)	
Delivery before	0.0681	0.0680	0.0689	−0.0009
	(0.252)	(0.252)	(0.253)	
Length of stay (in days) before delivery	0.3291	0.3237	0.3801	−0.0564***
	(1.677)	(1.664)	(1.799)	
Gestational hypertension	0.0402	0.0400	0.0418	−0.0018
	(0.196)	(0.196)	(0.200)	
Pre-eclampsia	0.0594	0.0596	0.0575	0.0021
	(0.236)	(0.237)	(0.233)	
Haemorrhage in early pregnancy	0.0222	0.0220	0.0243	−0.0023**
	(0.147)	(0.147)	(0.154)	
Diabetes mellitus in pregnancy	0.0178	0.0176	0.0201	−0.0025***
	(0.132)	(0.131)	(0.140)	
Maternal care for other conditions	0.0381	0.0383	0.0367	0.0015
	(0.191)	(0.192)	(0.188)	
Multiple gestation	0.0068	0.0066	0.0091	−0.0025***
	(0.082)	(0.081)	(0.095)	
Known or suspected malpresentation of fetus	0.0436	0.0432	0.0474	−0.0042***
	(0.204)	(0.203)	(0.213)	
Known or suspected disproportion	0.0454	0.0450	0.0495	−0.0045***
	(0.208)	(0.207)	(0.217)	
Known or suspected abnormality of pelvic organs	0.1221	0.1179	0.1616	−0.0438***
	(0.327)	(0.322)	(0.368)	
Known or suspected fetal abnormality and damage	0.0052	0.0051	0.0054	−0.0003
	(0.072)	(0.071)	(0.073)	
Known or suspected fetal problems	0.0542	0.0541	0.0553	−0.0012
	(0.226)	(0.226)	(0.229)	
Polyhidrammios	0.0098	0.0098	0.0100	−0.0002
	(0.099)	(0.099)	(0.100)	
Disorders of amniotic fluid and membranes	0.0166	0.0167	0.0156	0.0010
	(0.128)	(0.128)	(0.124)	
Premature rupture of membranes	0.0141	0.0137	0.0178	−0.0042***
	(0.118)	(0.116)	(0.132)	
Placental disorders	0.0240	0.0243	0.0220	0.0023**
	(0.153)	(0.154)	(0.147)	
Placenta praevia	0.0100	0.0099	0.0108	−0.0009
	(0.099)	(0.099)	(0.103)	
False labour	0.0713	0.0710	0.0737	−0.0027
	(0.257)	(0.257)	(0.261)	
Prolonged pregnancy	0.0100	0.0102	0.0085	0.0017**
	(0.100)	(0.100)	(0.092)	
Infectious and parasitic diseases classifiable elsewhere	0.0151	0.0153	0.0135	0.0018**
	(0.122)	(0.123)	(0.116)	
Observations	253124	228948	24176	253124

Note: Means with standard deviation in parenthesis. Difference in means test * p<0.1, ** p<0.05, *** p<0.01. The column 'analytical sample' is women who choose from their choice set and are included in the main analysis. The column 'out choice set' are women who choose, either, antenatal care or child delivery from providers outside their choice set. The sample size for distances for midwife-led providers and obstetrician-led providers are 47489 and 205635 respectively.

Table (A2.2) Descriptive statistics analytical samples in 2011 and 2015

	2011	2015	Diff. Means
Age 1 (<21 years)	0.2713 (0.445)	0.2648 (0.441)	−0.0065**
Age 2 (21-25 years)	0.2813 (0.450)	0.2774 (0.448)	−0.0038
Age 3 (26-30 years)	0.2121 (0.409)	0.2172 (0.412)	0.0050*
Age 4 (31-35 years)	0.1402 (0.347)	0.1434 (0.350)	0.0032
Age 5 (>35 years)	0.0951 (0.293)	0.0972 (0.296)	0.0021
Delivery before	0.0134 (0.115)	0.0000 (0.005)	−0.0134***
Length of stay (in days) before delivery	0.3340 (1.615)	0.3044 (1.622)	−0.0296**
Gestational hypertension	0.0430 (0.203)	0.0424 (0.201)	−0.0006
Pre-eclampsia	0.0598 (0.237)	0.0458 (0.209)	−0.0139***
Haemorrhage in early pregnancy	0.0115 (0.107)	0.0069 (0.083)	−0.0046***
Diabetes mellitus in pregnancy	0.0158 (0.125)	0.0179 (0.132)	0.0021**
Maternal care for other conditions	0.0096 (0.097)	0.0094 (0.097)	−0.0001
Multiple gestation	0.0062 (0.079)	0.0065 (0.080)	0.0003
Known or suspected malpresentation of fetus	0.0486 (0.215)	0.0427 (0.202)	−0.0059***
Known or suspected disproportion	0.0520 (0.222)	0.0444 (0.206)	−0.0076***
Known or suspected abnormality of pelvic organs	0.1003 (0.300)	0.0962 (0.295)	−0.0041*
Known or suspected fetal abnormality and damage	0.0026 (0.051)	0.0026 (0.050)	−0.0001
Known or suspected fetal problems	0.0309 (0.173)	0.0539 (0.226)	0.0231***
Polyhidrammios	0.0126 (0.112)	0.0148 (0.121)	0.0021**
Disorders of amniotic fluid and membranes	0.0215 (0.145)	0.0259 (0.159)	0.0044***
Premature rupture of membranes	0.0128 (0.112)	0.0203 (0.141)	0.0075***
Placental disorders	0.0043 (0.065)	0.0082 (0.090)	0.0039***
Placenta praevia	0.0090 (0.095)	0.0076 (0.087)	−0.0014**
False labour	0.0148 (0.121)	0.0155 (0.123)	0.0007
Prolonged pregnancy	0.0110 (0.104)	0.0118 (0.108)	0.0008
Infectious and parasitic diseases classifiable elsewhere	0.0198 (0.139)	0.0125 (0.111)	−0.0073***
Observations	40967	34818	75785

Note: Means with standard deviation in parenthesis. Difference in means test * p<0.1, ** p<0.05, *** p<0.01. This table compares women characteristics between 2011 and 2015 to examine if there is a systematic variation which might explain trends in choice of provider types.

Appendix B: Continuity and choice model - theory extension

A population of women is distributed uniformly along a Hotelling road of unit length. Providers of ante natal and delivery care are located at each end of the road with the midwife led provdier at 0 and the obstetrician led provider at 1. Utility for a women located at distance $d \in [0,1]$ from the midwife-led provider (distance $(1-d)$ from the obstetrician-led provider) for the four possible combinations of provider for ante-natal and delivery care are

$$
\begin{aligned}
V^{MM}(d) &= v^{aM} + v^{bM} + C^{MM} - (\delta^a + \delta^b)d \\
V^{OO}(d) &= v^{aO} + v^{bO} + C^{OO} - (\delta^a + \delta^b)(1-d) \\
V^{MO}(d) &= v^{aM} + v^{bO} + C^{MO} - \delta^a d - \delta^b(1-d) \\
V^{OM}(d) &= v^{aO} + v^{bM} + C^{OM} - \delta^a(1-d) - \delta^b d
\end{aligned}
$$

$v^{aM}$and v^{bM} are utility from choosing the midwife provider for ante natal care and delivery (birth) and v^{aO}, v^{bO} utility from choosing the obstetrician provider. Plausibly, utility from midwife led care is smaller than utility from care in better equipped obstetrician led units: $v^{aM} < v^{aO}$, $v^{bM} < v^{bO}$, $s^M < s^O$. We might also expect that the utility gain from delivery care in the obstetrician-led unit is greater than the utility gain from ante-natal care: $v^{bO} - v^{bM} > v^{aO} - v^{aM}$.

C^{JK} is the utility from the *combination* of ante-natal care at provider $J = M, O$ and delivery provider $K = M, O$. The combination of providers chosen will affect communication between the staff providing ante-natal and delivery care and thus possibly the outcome of the process. We might expect that communication within the same provider would be better than between providers and so C^{MM} and C^{OO} would be greater than C^{MO} and C^{OM}.

δ^a and δ^b are the marginal cost of distance travelled for ante-natal and delivery. The cost of distance is greater for delivery than for ante-natal care ($\delta^b > \delta^a$) since birth is a more time critical process. Thus utility increases for women the closes they are to the type of unit they will choose for delivery. V^{MM} and V^{OM} decrease with d and V^{OO} and V^{MO} increase.

Figure B2.1 plots utility against location (d) for the four possible combinations of ante-natal and delivery provider.[5] With the assumptions about the utility from care in the different types of provider, the values of continuity, and the marginal utilities of distance implicit in the Figure B2.1, women who are a short distance from the midwife provider ($d \leq d^{MMOM}$) choose continuity in the midwife provider. Women located in $(\hat{d}^{MMOM}, \hat{d}^{OMMO}]$ choose ante natal care in the obstetrician led unit and then switch to the midwife provider for delivery. Those located in $(\hat{d}^{OMMO}, \hat{d}^{MOOO}]$ who are near to the obstetrician provider choose to have ante-natal and delivery care in the obstetrician provider.

Different types of women may have different preferences and so $V^{JK}(d)$ and have the mix of choices will change. For example, women who place a slightly greater value on continuity in the midwife provider would never choose ante-natal care in the obstetrician unit and delivery in the midwife unit, irrespective of their distances from each type of provider.

[5]We normalise the utility from the outside option of home care (not receiving ante-natal or delivery care in one of the two providers) to zero and assume that the maximum of $V^{JK}(d)$ from combinations of providers is strictly positive wherever the woman is located.

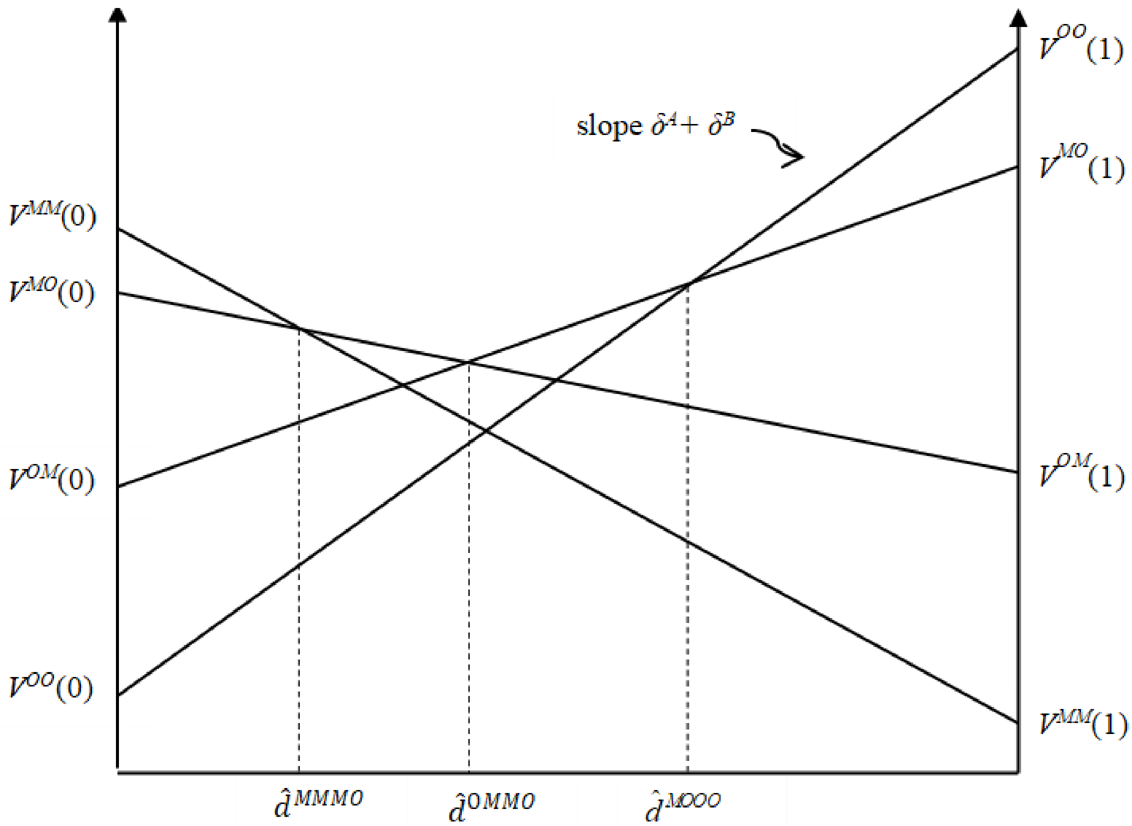

Figure (B2.1) The theoretical model with four options chosen

Chapter 3

Does opening more midwife-led maternity units improve quality of care and women's welfare?

3.1 Introduction

Policymakers in Lima aim to ensure an appropriate configuration of maternity facilities across the city. The most specialised facilities offer a broader range of maternity and obstetrics services, employ more highly skilled staff and are located within large hospitals offering back-up support services such as intensive care units. These facilities are more costly to setup and run, and are intended for women and babies at highest risk. Ideally, women at progressively lower levels of risk should receive their maternity care at progressively less specialised facilities. But there is no mechanism to ensure that women sort themselves among facilities according to their risk status.

Maternity units in Peru are paid according to the number and type of patients cared for, with funding reflecting patient flows. More specialised facilities are paid higher tariffs. This can lead to budgetary pressure, exacerbated if there is an increasing tendency for patients to seek care in higher level facilities, as established in Chapter 2.

Budgetary pressure can be eased in three ways. First, the tariff paid to each facility could be re-negotiated. Second, more midwife-led maternity units for giving birth, could be built, thereby reducing average distance and travel costs for patients. At the margin, this might change the balance between preferences in favour of continuity of care and away from better equipped facilities. Third, expectant mothers' perceptions about outcomes in midwife-led and obstetrician-led maternity units could be changed.

The Health Ministry of Peru has applied the second strategy in Lima opening three new midwife-led maternity providers over the five year period considered in the study, from 2011 to 2015. The first maternity unit was opened in March 2012, the second in June 2013 and the last one in June 2015.

I examine the effect of the policy on a set of quality of care measures and women's welfare.

From the quality of care perspective, following Donabedian's schema (Donabedian, 2005), I conceptualise its possible impacts on structural, process and outcomes. First, consider the effects on the choice of high structural quality obstetrician-led providers. A new midwife-led maternity unit requires investment in structural quality. I classify this investment as low structural quality compared with obstetrician-led maternity units, which are classified as high structural quality providers, due to the characteristics of staffing and equipment required, i.e Peruvian midwife-led maternity units do not require intensive care units (Ministerio de Salud del Peru, 2004). Then it is expected that a new midwife-led maternity unit, having reduced the distance needed to travel to access care, should reduce choice of obstetrician-led providers. Second, consider the effects in improving process quality measured as an increase in continuity of care and reduction of caesarean sections (C-sections).I measure process quality as continuity of care defined as women choosing the same provider for antenatal care and child delivery. It is then expected that women who choose the new midwife-led maternity unit for antenatal care should also choose the same provider for child delivery, increasing continuity of care. Moreover, new midwife-led maternity units by themselves and continuity of care in midwife-led maternity units are associated with another measure of process quality, namely C-sections. C-sections are rising worldwide (Boerma et al., 2018) and, as obstetricians are suspected of performing unjustified C-sections, as I will show in Chapter 4, there is a growing literature that argues that midwife-led maternity units can reduce C-section rates safely (McLachlan et al., 2012; Tracy et al., 2013; Betrán et al., 2018; Lancet, 2018; Wiklund et al., 2018). Thus more midwife-led maternity units can potentially increase continuity of care and reduce C-sections.

Third, consider the effects in improving health outcomes. It is also argued that midwife-led maternity units and midwifery-led continuity of care improve health outcomes defined as a reduction of health complications (Long et al., 2016; Renfrew et al., 2014; Sandall et al., 2016). I examine the effect of implementing new midwife-led maternity units, particularly for haemorrhage, sepsis, puerperal infections, perineal laceration and retained placenta and membranes.

Common to the literature mentioned above is the use of observational studies or randomised controlled trials (RCT) in pre-existing providers. Thus their findings are restricted to the set of women who arrive at the hospital and, for RCT, for women who agree to participate in the research, those women are potentially different from the non-participant population.

In contrast, I seek to understand the effect of the introduction of three new midwife-led providers in three different geographical areas and evaluate the effect of the policy on women that live in those areas.

From the women's welfare perspective, an increase in the availability of midwife-led maternity units increases women's choice set. This means that changes in welfare can be estimated as changes in consumer surplus (Train, 2003). To the best of my knowledge this is the first research that examines the effect of increasing the choice set in the context of child deliveries; the closest in comparison examining this effect is in the context of coronary heart disease (Gaynor et al., 2016).

Accordingly, the contribution of this research to the literature is to examine if there is a gain in consumer surplus due to an expansion of the choice set. Second, I look at the effect of increasing the number of midwife-led maternity units on changes in demand at obstetrician-led providers and continuity of care depends on the maternity unit's location relative to existing maternity providers. Third the potential reduction in C-sections and improvements in health outcomes is more likely to occur if the new midwife-led maternity unit does not compete with another midwife-led maternity unit and is close to an obstetrician-led maternity unit.

I analyse patient-level administrative data relating to 263,503 child deliveries from 2011 to 2015 in Lima. All patients were covered financially by the Seguro Integral de Salud-SIS, a public health insurance programme, health providers are officially organised geographically into 45 micro-networks. I evaluate the effect of the introduction of three new midwife-led maternity units in the population attached to three of these micro-networks.

For evaluating the effect of the policy on quality of care I construct a panel of 60 monthly periods for 45 micro-networks. I use synthetic difference in difference (SDID) methods, which combine the strengths of difference in difference (DID) and synthetic control (SC), to examine whether women's quality of care indicators for the post-policy period of a micro-network affected by the policy, differs from its pre-policy period.

For evaluating the effect of the policy on consumer surplus I use a conditional logit regression using the information about women that live in the three micro-networks affected by the policy.

The remainder of this chapter is structured as follows. In section 3.2 I set out the empirical approach. Section 3.3 presents the data and descriptive statistics and section 3.4 reports the results. A discussion and the concluding remarks are presented in section 3.5.

3.2 Empirical approach

In this section I propose using the synthetic difference in difference approach for evaluating the effect of the policy of opening new midwife-led maternity units on quality of care indicators and conditional logit for estimating its effects on consumer surplus.

3.2.1 Effects on quality of care

During the period of the analysis three new midwife-led maternity units were opened in three micro-networks. Micro-network 1 is the micro-network where the first new midwife-led maternity unit was opened in March 2012, micro-network 2 has the second maternity unit opened in June 2013 and micro-network 3 has the last maternity unit opened in June 2015.

I propose to measure the effect of each new provider by using synthetic difference in difference (SDID). First I present the synthetic control (SC) method.

Following the Abadie et al. (2010) notation there are J+1 micro-networks where the first micro-network is treated and those with no new maternity facility, in this case from 4 to 45, serve to construct the synthetic control. The outcome observed for each micro-network is $Y_j = (Y_{j1}, ..., Y_{jT0}, ..., Y_{jT})$ where t is measured in months. $T0$ is the first intervention month. The observed outcome is:

$$Y_{jt} = Y_{jt}^N + \tau_{jt} D_{jt} = Y_{jt}^N + (Y_{jt}^I - Y_{jt}^N) D_{jt} = Y_{jt}^I D_{jt} + Y_{jt}^N (1 - D_{jt}) \tag{3.1}$$

where Y_{jt}^N is the observed outcome for micro-network j at time t in the absence of intervention (the entry of a new maternity unit). τ_{jt} is the effect of the intervention measured as the difference between the state of intervention vs. no intervention: $\tau_{jt} = Y_{jt}^I - Y_{jt}^N$, and D_{jt} is the indicator that the micro-network is exposed to the intervention in period t and is set at zero for the control group.

Although the outcome with intervention for micro-network 1 Y_{1t}^I is observed, Y_{1t}^N the counterfactual needs to be estimated as it is not observed. Following Abadie et al. (2010), for a model with no covariates, this is equivalent to estimating using the following factor model:

$$Y_{jt}^N = \delta_t + \lambda_t \mu_j + \epsilon_{jt} \tag{3.2}$$

δ_t is a time fixed effect, μ_j are unobserved micro-network common factors which are time varying according to λ_t and ϵ_{jt} is the error term. Then using weights on information of the non-treated group τ_{1t} is estimated as:

$$\hat{\tau_{1t}}^{sc} = Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt} \tag{3.3}$$

for a post policy period t, where w_j^* is the weight on control unit j. w_j^* are chosen so that the treated micro-network has similar outcomes to $\Sigma w_j^* Y_{jt}$ over the pre-intervention periods.

To ensure that the assumption of no interference between units holds (Rosenbaum, 2007) I include in the control donor pool only micro-networks that are at least 5 kilometres away from each new maternity unit. In doing so, from 42 possible control units, I have 40 control micro-networks for the first maternity unit and 39 each for the second and third maternity units.

Below I describe the estimation procedure using the number of micro-networks in the control donor pool for the first micro-network, for the other two micro-networks the numbers should be adjusted accordingly.

For evaluating the significance of the estimation I use placebo tests using each non treated unit as if it was treated by the policy. I follow this procedure switching the treated micro-network to the control donor pool and then performing synthetic control analysis as if each micro-network of the donor pool were affected by the policy. I follow Kreif et al. (2016) in using the distribution of the estimated average treatment effect ATTs of all 41 micro-networks (one of the treated and 40 placebo test) to infer the significance of the estimation effect on the treated micro-network.

I contrast the results of the synthetic control approach with difference in difference (DID), which have been used extensively in observational studies to address causality (Cameron and Trivedi, 2005; Angrist and Pischke, 2009). The difference in difference (DID) approach takes advantage of the existence of control micro-networks not affected by the policy. The intuition behind this method is that there are 40 micro-networks unaffected by the policy and their information is used to estimate what would have happened to the outcomes if the policy had not been implemented in the treated micro-network, assuming parallel trends in unobserved characteristics.

The DID approach is specified for micro-network $j = 1, .., J$ at time $t = 1, .., T$ by the following equation:

$$Y_{jt} = \tau^{did} D_{jt} + \delta_t + \lambda \mu_j + \epsilon_{jt} \tag{3.4}$$

where D_{jt} takes the value of 1 if micro-network j is 'treated' in period t (has a new midwife-led unit), δ_t are common time fixed effects and μ_j are micro-network unobserved fixed effects at a constant rate by time measured with λ, ϵ_{jt} is a random error term, and the coefficient of interest is τ^{did} which measures the effect of the policy.

Synthetic control generalises DID by allowing that the micro-network fixed effect, μ_t, can vary over time with λ_t. But as this is not observed this is approximated in the estimation procedure. The difference in difference (fixed effect) model removes the micro-network fixed effect in the estimation but does not include the unit weights w_j^* in the estimation.

The synthetic difference in difference (SDID) innovates by proposing the inclusion of both elements in the model (Arkhangelsky et al., 2019), solving the following equation:

$$(\hat{\mu}, \hat{\delta}, \hat{\tau}^{sdid}) = arg \min_{\delta,\mu,\tau} \sum_{i=1}^{N} \sum_{i=1}^{T} (Y_{jt} - \delta_t - \lambda\mu_j - D_{jt}\tau)^2 \hat{\omega}_j \hat{\lambda}_t \tag{3.5}$$

Here the weight is the product of unit weights $\hat{\omega}_j$ and time weights $\hat{\lambda}_t$. Arkhangelsky et al. (2019) show that SDID is a double bias reduction method and has better bias properties than SC and DID (see (Arkhangelsky et al., 2019) for details). For SC and SDID I perform a placebo test using the other micro-networks of the donor pool to compute p-values. SC and SDID is estimated with the user-written 'synthdid' R command (Arkhangelsky et al., 2019). In the case of DID I report point estimates and p-values using the 'xtreg' Stata command.

I present the results with no covariates. This is first, because the current version of SDID code, which is the preferred method, does not accommodate covariates. Second, because there is no marked differences between synthetic control with covariates and with no covariates. To argue for this I use the user written 'syth' Stata command (Abadie et al., 2011) for fitting the synthetic control estimation with covariates (see Table A3.1 in the Appendix). Third, because SDID not only accounts for differences between the synthetic control and the observed series before the policy switching, but also the reference control from which the treatment is compared. And fourth, consistency of the SDID estimator is argued if the weights are well chosen even if the model is not correctly specified (Arkhangelsky et al., 2019), which could be the case if the inclusion of covariates were relevant.

There are two other candidate methods for evaluating this policy that are not considered in this chapter; Propensity Score Matching (PSM) and Interrupted Time Series (ITS). Both of them used extensively in observational studies to address causality (Angrist and Pischke, 2009; Cameron and Trivedi, 2005). Propensity Score Matching (Rosenbaum and Rubin, 1983), only corrects bias for observed characteristics but not for unobserved characteristics. This involves to match treated and untreated micro-networks with similar characteristics to evaluate the effect of the treatment. ITS relies on a single serie of observation, in this case the treated micro-network, before and after the policy and has the potential to control for unobserved characteristics. But DID, which controls for observed and unobserved characteristics, uses also the information of the no-treated micro-networks as controls and has better properties than PSM and ITS. In summary, as DID has better properties than PSM and ITS, and in turn SDID better properties than DID, it will be less informative to use ITS and PSM for evaluating the policy analysed in this chapter.

3.2.2 Effect on welfare

The consumer surplus is the utility that women receives in the choice situation and measures consumer's welfare (Train, 2003). I first model women's utility function using a logit choice model, then use the log sum approach to estimate the variation on consumer surplus due to the introduction of new maternity units which change women's choice set.

Choice sets are constructed using the same criteria as in Chapter 2. In particular the choice set is a set of possible combinations of antenatal care and child delivery providers inside a given distance (see Chapter 2 for details).

There are two main differences between this chapter and Chapter 2. First, in this chapter I only use the definition of provider continuity of care: women choosing the same provider for antenatal care and child delivery, rather than including network continuity of care as in Chapter 2. This is because I am interested in the effect of the new midwife-led maternity units in continuity of care, thus it is appropriate to focus on women choosing these very new midwife-led maternity units for antenatal care as well as for child delivery. Second, in this chapter I only examine the policy on women who live in the jurisdiction of the three new midwife-led maternity units, so the sample is reduced accordingly.

I estimate the following random utility model (McFadden, 1973) for woman $i = 1, \ldots, I$ utility from choice of a combination $k \in \{a, b\}$ of an antenatal care provider $a(a = 1, \ldots, N^A)$ and child delivery provider $b(b = 1, \ldots, N^B)$ at time $t = 1, \ldots, T$:

$$\begin{aligned} U_{ik} &= V_{ikt} + \nu_{ikt} \\ &= C_i\beta_C + q_i^{chd}\beta_{q_{chd}} + q_i^{anc}\beta_{q_{anc}} + D_{ik}^{anc}\beta_{D^{anc}} + D_{ik}^{chd}\beta_{D^{chd}} + \nu_{ikt} \end{aligned} \tag{3.6}$$

where V_{ikt} depends on a vector of quality measures that includes continuity of care $C_i \in \{0, 1\}$, structural quality for child delivery q_i^{chd} that takes the value of 1 if woman i chooses child delivery in an obstetrician-led maternity unit and zero in a midwife-led maternity unit, and analogously constructed structural quality for antenatal care q_i^{anc}.

Distances are for antenatal care D^{anc} and for child delivery D^{chd}. ν_{ikt} subsumes unobserved characteristics and random utility (in the estimated model I interact distances with women's characteristics).

To estimate the consumer surplus I use the log sum approach as in Train (2003). The expected consumer surplus can be estimated as:

$$E(CS_i) = \frac{1}{\alpha_i} E[max_k(V_{ik} + \epsilon_{ik}, \forall_k)] \tag{3.7}$$

where α_i, in Train's specification, is the marginal utility of income. In that case the division translates the expected utility into monetary units. According to Williams (1977) and Small and Rosen (1981) if ϵ_{ik} have identical and independent extreme value distribution and utility is linear in income, the expectation becomes:

$$E(CS_i) = \frac{1}{\alpha_i} ln\left(\sum_{k=1}^{K} e^{V_{ik}}\right) + Constant \tag{3.8}$$

The change in consumer surplus for a change in the choice set is:

$$\Delta E(CS_i) = \frac{1}{\alpha_i}\left[ln\left(\sum_{k=1}^{K^1} e^{V_{ik}^1}\right) - ln\left(\sum_{k=1}^{K^0} e^{V_{ik}^0}\right)\right] \tag{3.9}$$

where the superscripts 1 and 0 correspond to the situation after the increase in the choice set and before the increase in the choice set, respectively.

In my case I measure the consumer surplus in terms of distance, using the constant marginal disutility of distance to child delivery $\beta_{D^{chd}}$, as in Gaynor et al. (2016). The measure of the change in consumer surplus is the reduction in travel distance expressed in kilometres. First

I fit equation (3.6) with conditional logit regression for all women in three micro-networks for all periods (pooled regression). Second I estimate the consumer surplus as in equation (3.9), this is the log sum of the expected utility in the situation with the extended choice set, due to the introduction of the policy of opening new midwife-led maternity units, and subtract this value from the log sum of expected utility estimated when dropping the three new midwife-led maternity units from women's choice set, the pre-policy situation, divided by the negative of the coefficient on distance to child delivery providers. Third, I bootstrap the estimated consumer surplus expressed in kilometres to obtain standard errors to test if there are differences in consumer surplus gains between the three micro-networks.

3.3 Data

3.3.1 Sources and variables

I use administrative data from the Peruvian public health insurance programme from 366 facilities officially organised geographically in 45 micro-networks, and grouped into eight categories indicative of their structural capabilities. From the 317,305 cleaned observations on child deliveries I identify 287,460 women where I have the information on the address of the facility which was most frequently used by those women for non-antenatal and child-delivery care. These information is used to construct the proxy of the women's homes. The details are described in the introduction of this thesis.

Of these women, 263,503 are attached to a micro-network[1]. The difference, 23,957, are women whose most-used provider is a higher level provider not under the jurisdiction of a micro-network and most of them have only one attendance, the delivery. For them there is no information of the micro-network of origin, and so they are excluded from the analysis.

I collapse the data on 263,503 individuals to panel data with information for 45 micro-networks and 60 monthly periods.

For the welfare analysis I use information on 17,450 women who live in the three micro-networks affected by the policy that choose from the constructed choice set. The use of a sample specific to the jurisdiction of the three new midwife-led maternity units allows for modelling the differences in women's preferences of women in these areas that potentially might be different from the overall population.

I classify quality of care variables as structural, process and outcome variables defined as follows:

I use a structural quality variable that takes the value of 1 for women's choice of obstetrician-led maternity units for child delivery and zero for midwife-led maternity units for delivery. For process quality I use the C-section rate, and provider continuity of care defined as a woman choosing the same provider for antenatal care and child delivery.

For health outcomes I use information on maternal complications of birth, based on ICD10 codes[2] from the time of the delivery up to 28 days after discharge, using dummy variables for the presence of each complication per woman. The diagnoses are classified in five groups, according to their severity and frequency:

- Postpartum haemorrhage (ICD code O72)

[1] Chapter 2 considers an analytical sample with fewer child deliveries 228,948. This is because, although the number of women with distances is the same as in this chapter 287,460, the number of women that choose antenatal care and child delivery in the constructed choice sets are fewer.

[2] ICD10: International Statistical Classification of Diseases and Related Health Problems 10th Revision.

- Puerperal sepsis (O85)
- Other puerperal infections (O86)
- Perineal laceration of second, third and fourth degree (O70.1, O70.2 and O70.3)
- Retained placenta and membranes (O73)

At the start of the period in 2011 there were 47 providers equipped for child delivery, 33 midwife-led maternity units equipped only for vaginal delivery[3] and 14 obstetrician-led maternity units from medium to very high specialisation, as described in the introduction of this thesis. Figure 3.1 shows the map of Lima, with the distribution of the 36 midwife-led maternity units, identifying the three recently implemented, and 14 obstetrician-led maternity units.

There is a lack of planning about opening new midwife-led maternity units across the city. Most of them respond to local demand from the population that lives nearby. Although there are general guidelines, those are legal requirements, i.e the legal tenancy of land and connection to public services (Ministerio de Salud del Peru, 2005). The Public Projects System does not have any criteria on how to reject projects, such as for the short distance between midwife-led maternity units (Ministerio de Economia y Finanzas del Peru, 2011). Local politicians and pressure groups negotiates with policy-makers to open new maternity units, and together with land availability and local Ministry of Health's administrations capacity in the formulation of public projects make possible to open new maternity units, and this could be as examined in this chapter, even in places where the investment has lower returns.

Figure 3.2 shows the detail of three micro-networks in three geographical districts: the location of the new midwife-led maternity units, other nearby midwife-led maternity units, if any, inside the same district, and the nearest obstetrician-led maternity unit regardless of the distance.

Panel A depicts the district of "San Juan de Miraflores". This district has three micro-networks and before the policy there were three midwife-led maternity units, one for each micro-network. In this case the new midwife-led maternity unit competes with an existing midwife-led maternity unit, and there is also an obstetrician-led maternity unit nearby. I would expect that the potential impact of the new midwife-led maternity unit is low. Panel B depicts the "Chorrillos" district which has two micro-networks. Before the policy there were two midwife-led maternity units, one per micro-network. The nearest obstetrician-led maternity unit is not as near as that in micro-network 1. Panel C shows the "Comas" district which has two micro-networks. In this case there were no midwife-led maternity units in the district before the policy and the nearest obstetrician-led maternity unit is inside the geographical boundaries of the micro-network. I would hypothesise that the new midwife-led maternity unit could potentially attract lower risk pregnancies and could also reduce the C-section rate of this micro-network. As women in micro-network 3 had direct access to highly specialist procedures nearby it is no surprise that the C-section rates of this population is one of the highest, as I discuss in the following section.

3.3.2 Descriptive Statistics

Table 3.1 presents the descriptive statistics for the quality of care indicators and distance measures for the pre-policy period for each micro-network affected by the policy.

The first midwife-led maternity unit was implemented in March 2012, and there are 14 monthly periods in the pre-intervention period, the second in June 2013 with 29 months of pre-intervention

[3]There are also some obstetricians on duty to perform high risk vaginal deliveries, then I call these providers 'midwife-led' due to the type of the deliveries which are typically performed by midwives.

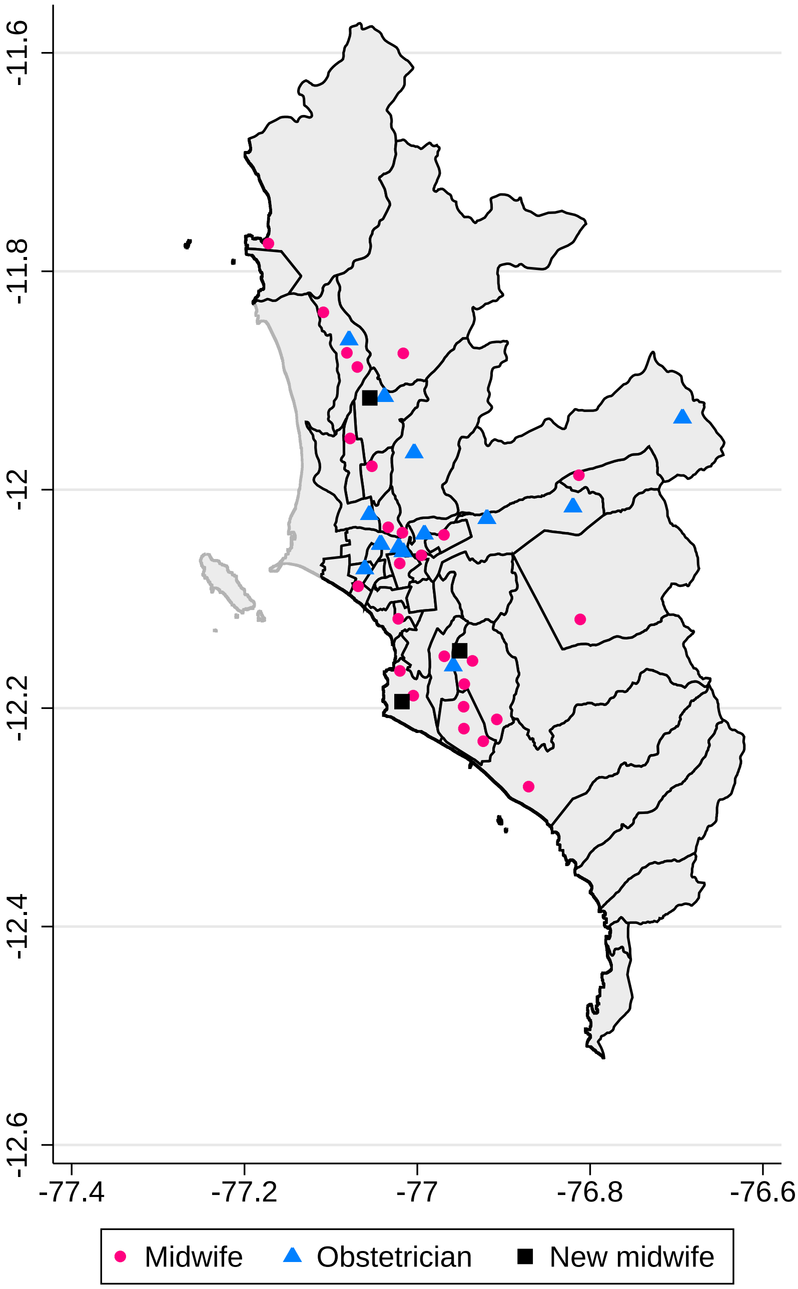

Figure (3.1) Distribution of child delivery providers and three new midwife-led maternity units in Lima, Peru

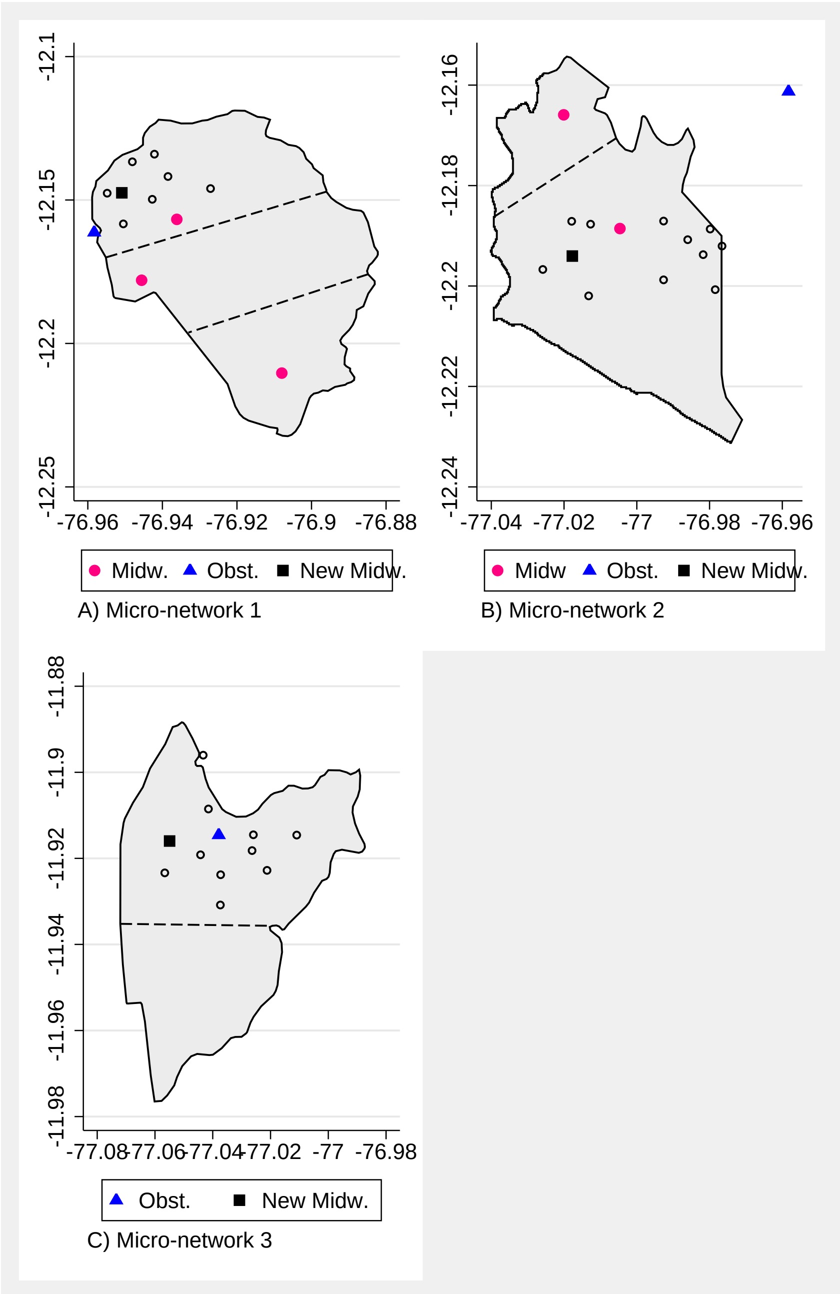

Figure (3.2) Detail of distribution of providers in three micro-networks

Note: The grey area corresponds to a geographical district and the dashed line approximately delimits a micro-network inside each district. In panel A the district includes three micro-networks and there are two micro-networks in panel B and C. The unfilled circles in each map, not included in the legend, show the location of local providers equipped only for antenatal care when the new midwife-led maternity units was opened. Aside from providers inside each micro-network I plot all midwife-led maternity units of the district, if any, and the nearest obstetrician-led provider regardless the distance.

Table (3.1) Mean and standard deviations of the pre-policy period per micro-network with new maternity units and for the overall period for untreated micro-networks

	MR 1	MR 2	MR 3	Other 42
Structural quality				
Choice of obstetrician-led provider for child delivery	0.572	0.712	0.985	0.807
	(0.495)	(0.453)	(0.121)	(0.395)
Process quality				
C-section	0.261	0.313	0.435	0.317
	(0.439)	(0.464)	(0.496)	(0.465)
Provider continuity of care in midwife-led unit	0.200	0.047	0.002	0.067
	(0.400)	(0.213)	(0.041)	(0.250)
Provider continuity of care in obstetrician-led unit	0.064	0.050	0.068	0.061
	(0.245)	(0.219)	(0.253)	(0.239)
Health outcomes				
Perineal laceration and obstetric trauma	0.002	0.003	0.001	0.005
	(0.044)	(0.051)	(0.029)	(0.070)
Retained placenta and membranes	0.027	0.019	0.006	0.017
	(0.163)	(0.136)	(0.078)	(0.128)
Postpartum haemorrhage	0.001	0.010	0.008	0.016
	(0.031)	(0.099)	(0.090)	(0.127)
Puerperal sepsis	0.027	0.025	0.006	0.010
	(0.163)	(0.155)	(0.079)	(0.098)
Other puerperal infections	0.011	0.027	0.027	0.038
	(0.103)	(0.161)	(0.161)	(0.192)
Distances				
Distance (in Km) travelled for delivery	3.272	6.805	3.652	5.280
	(7.112)	(5.998)	(5.184)	(5.887)
Distance (in Km) travelled for antenatal care	1.146	0.848	0.717	0.840
	(3.535)	(3.275)	(3.144)	(3.316)
Observations (deliveries)	1030	3113	7279	242523

Note: Standard deviations in parenthesis. All values, with the exception of distances measured in kilometres, are presented in ratios from 0 to 1. There is a reduction in the sample size compared to the number reported at the end of the table for provider continuity of care and distance for antenatal care. There are 898 for the first micro-network, 2,803 for the second micro-network, 6,503 for the third micro-network and 219,183 for the other 42 micro-networks. Standard deviation in parenthesis. The sample the other 42 micro-networks corresponds to the entire period 2011-2015 because in these micro-networks there is no pre or post policy period.

period and the last one in June 2015 with 53 months of pre-intervention period.

The first column first row value 0.572 means that 57% of women choose high structural quality obstetrician-led providers for child delivery in micro-network 1, the second column first row, 0.712, means that higher structural quality providers are preferred in 71% of the cases in micro-network 2 and in the third column first row, 0.985. This figure is almost 99% for micro-network 3.

The fourth column first row, 0.807, shows that these percentages contrast with 81% of preferences for higher structural quality obstetrician-led providers in the other 42 micro-networks. Of the overall percentage in the non-treated group, 81% suggest that there is a potential to introduce new midwife-led maternity units, because most women are choosing higher structural quality providers: obstetrician-led providers. It is also clear that the potential reduction of demand is higher in micro-network 3, where almost all women are choosing obstetrician-led providers for child delivery.

Figure 3.3 shows the monthly variation of choice of obstetrician-led delivery provider by micro-network before and after the policy compared with the change in distance to the nearest child delivery provider. The figure appears to show an effect of the new midwife-led unit for micro-network 3.

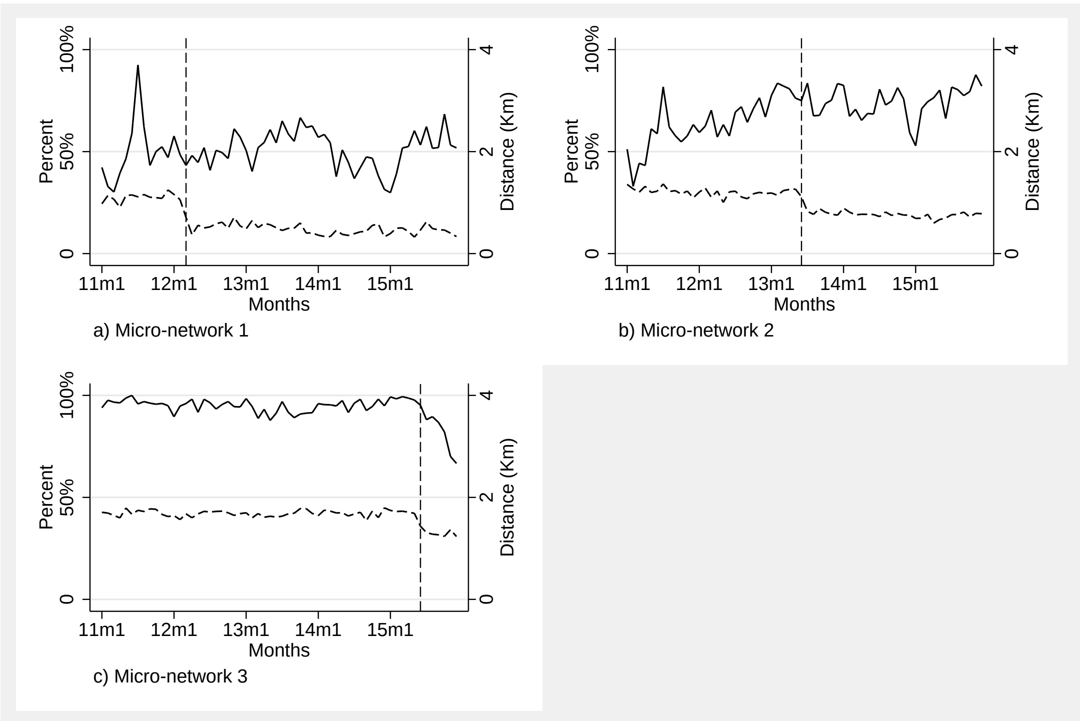

Figure (3.3) Reduction in distances and choice of obstetrician-led provider by micro-network

Note: A solid line depicts the percentage of women who choose obstetrician-led provider for child delivery and the dashed line the distance to the nearest child delivery provider before and after the introduction of a new midwife-led maternity unit by micro-network

The second row of table 3.1 shows that micro-network 3 has a higher C-section rate (44%) compared to non-treated micro-networks (32%), likely due to the direct access to a high-level obstetrician maternity unit inside its territorial boundaries. The rest of Table 3.1 is interpreted likewise.

Figure 3.4 presents the monthly C-section rates before and after the policy for each micro-network affected by the policy compared with the average of the other 42 micro-networks. Women that live in the jurisdiction of micro-network 3 have higher C-section rates than the average woman, and this is likely to be related to its location near a high structural quality provider (and C-section performer).

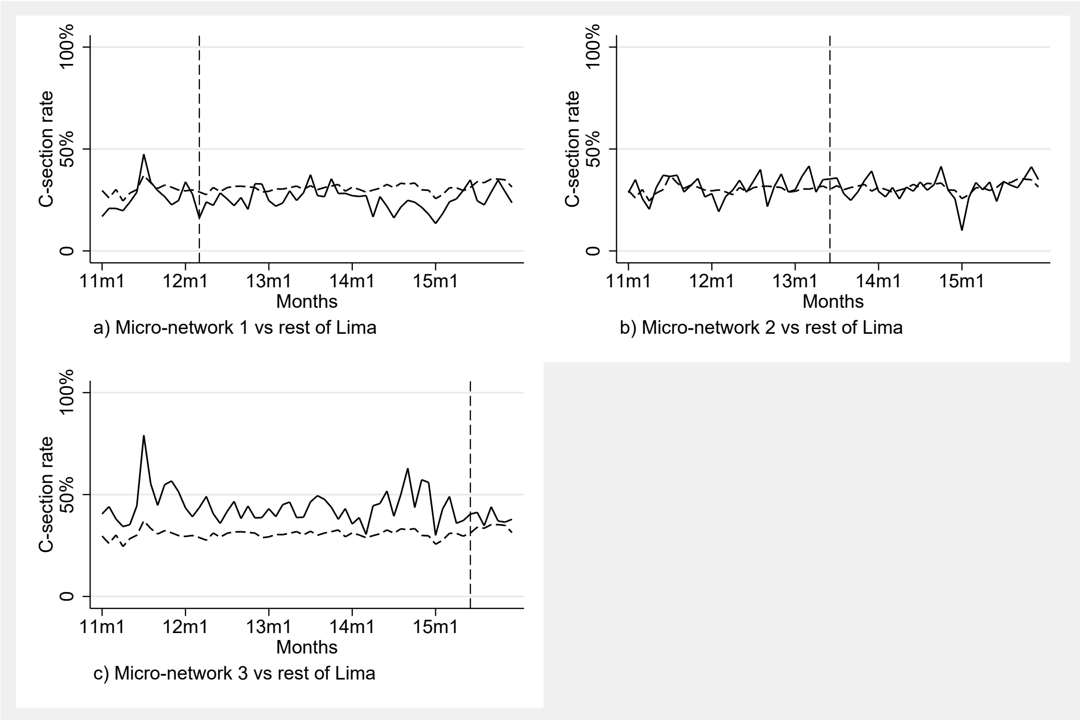

Figure (3.4) Comparison of C-section rates by jurisdiction of new midwife-led maternity units and time of the policy

Note: The bold line represents the actual monthly C-section rate in each of the micro-networks where a new midwife-led maternity unit was opened, the dashed line is the average C-section rate of the remaining 42 micro-networks not affected by the policy. The vertical dashed line signals the time when the new midwife-led maternity unit was implemented. In a) the new maternity unit was attending deliveries from March 2012, in b) from June 2013, and in c) from June 2015.

3.4 Results

This section presents the results for quality of care variables estimated by DID, SC and SDID, from the conditional logit for welfare analysis, and the policy implications.

3.4.1 Effects on quality of care

In this subsection I present the results showing the impact of the new facilities on quality of care estimated by DID, SC and SDID. Firstly I compare the results across methods, secondly I compare the results across quality of care outcomes within micro-networks, and thirdly I compare the quality of care outcomes across micro-networks.

Table 3.2 presents the results for quality of care variables using difference in difference (DID) (column 1), synthetic control estimation (SC) (column 2) and synthetic difference in difference (SDID) (column 3).

Table (3.2) Results for quality of care by micro-network

	(1) DID (p-value)		(2) SC (p-value)		(3) SDID (p-value)	
Micro-network 1						
Structural quality						
Choice of obstetrician-led providers for child delivery	-0.099	(<0.01)	-0.118	(0.02)	-0.122	(0.01)
Effect on process quality						
C-sections	-0.024	(<0.01)	-0.024	(0.49)	-0.018	(0.59)
Provider continuity of care in midwife-led unit	0.070	(<0.01)	0.090	(<0.01)	0.093	(<0.01)
Provider continuity of care in obstetrician-led unit	0.005	(0.27)	0.001	(0.96)	-0.010	(0.72)
Effect on health outcomes						
Haemorrhage	0.001	(0.42)	-0.002	(0.65)	0.001	(0.82)
Sepsis	-0.012	(<0.01)	-0.006	(0.37)	-0.011	(0.20)
Puerperal infection	-0.002	(0.35)	-0.004	(0.60)	-0.001	(0.89)
Perineal laceration	-0.001	(0.27)	-0.004	(0.32)	-0.008	(0.33)
Retained placenta and membranes	-0.013	(<0.01)	-0.013	(0.22)	-0.008	(0.32)
Micro-network 2						
Structural quality						
Choice of obstetrician-led providers for child delivery	-0.003	(0.67)	-0.014	(0.73)	-0.024	(0.42)
Effect on process quality						
C-sections	-0.014	(<0.01)	-0.017	(0.56)	-0.011	(0.64)
Provider continuity of care in midwife-led unit	0.057	(<0.01)	0.054	(0.11)	0.054	(0.06)
Provider continuity of care in obstetrician-led unit	0.012	(<0.01)	0.003	(0.88)	-0.001	(0.98)
Effect on health outcomes						
Haemorrhage	0.018	(<0.01)	-0.001	(0.76)	-0.001	(0.97)
Sepsis	-0.008	(<0.01)	-0.005	(0.46)	-0.006	(0.43)
Puerperal infection	0.006	(0.05)	0.021	(0.08)	0.018	(0.20)
Perineal laceration	-0.0002	(0.85)	0.004	(0.33)	0.003	(0.35)
Retained placenta and membranes	-0.006	(<0.01)	0.002	(0.87)	0.001	(0.86)
Micro-network 3						
Structural quality						
Choice of obstetrician-led providers for child delivery	-0.173	(<0.01)	-0.093	(0.03)	-0.108	(<0.01)
Effect on process quality						
C-sections	-0.091	(<0.01)	-0.035	(0.26)	-0.102	(<0.01)
Provider continuity of care in midwife-led unit	0.079	(<0.01)	0.048	(0.14)	0.055	(0.06)
Provider continuity of care in obstetrician-led unit	-0.010	(0.04)	0.0002	(0.97)	-0.001	(0.99)
Effect on health outcomes						
Haemorrhage	-0.012	(<0.01)	-0.002	(0.69)	-0.001	(0.90)
Sepsis	-0.008	(<0.01)	-0.008	(0.40)	-0.0002	(0.99)
Puerperal infection	0.005	(0.16)	-0.015	(0.15)	-0.011	(0.32)
Perineal laceration	0.004	(0.52)	-0.013	(0.09)	-0.013	(0.09)
Retained placenta and membranes	-0.009	(0.61)	-0.002	(0.89)	0.002	(0.84)

Note: The coefficients present the effect of opening new midwife-led maternity units, in each micro-network, on quality of care outcomes. Column 1 presents the difference in difference (DID) estimation results with micro-network fixed effects results, p-values estimated by regression method. In column 2 synthetic control (SC) and in column 3 synthetic difference in difference (SDID) with p-values based on placebo test.

Comparison of results for DID, SC and SDID

To explain the differences in empirical results for DID, SC and SDID I focus on a single outcome in a single micro-network: choice of obstetrician-led providers for child delivery in micro-network 3. The results discussed correspond to the first line and columns 1 (DID), 2 (SC) and 3 (SDID) for the third block of results in Table 3.2.

Figure 3.5 depicts the choice of obstetrician-led providers in micro-network 3 (solid line) and the average choice of obstetrician-led provider for the other 40 micro-networks (dashed line). The parallel trend assumption required by DID can be tested in the pre-policy period (before the the vertical line).

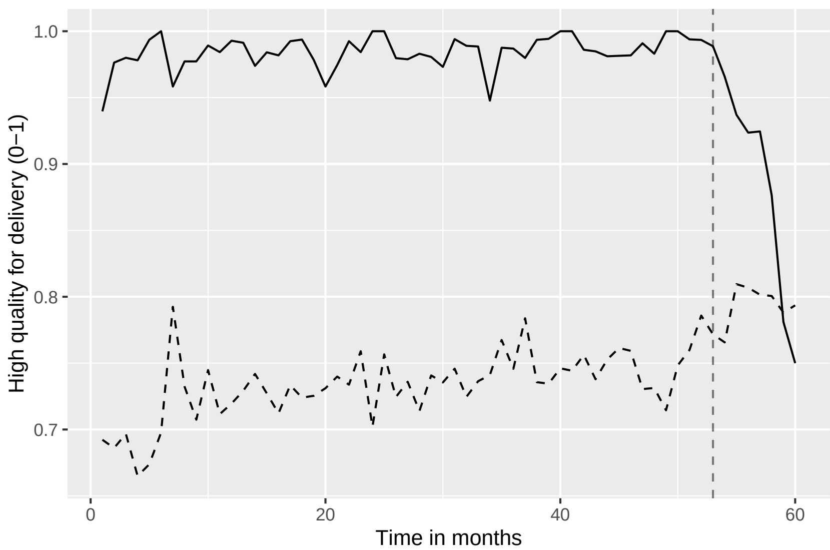

Figure (3.5) Choice of obstetrician-led provider (high structural quality) for child delivery in micro-network 3

Note: Choice of obstetrician-led provider for child delivery in micro-network 3 (bold line) and its average on the other 39 micro-networks not affected by the policy (dashed line). The vertical dashed line signals the time when the new midwife-led maternity unit was implemented, on June 2015.

The parallel trend assumption requires outcomes increase or decrease, or remain constant, for the treated micro-network and the other control micro-networks at the same time in the pre-policy period. The solid line in Figure 3.5, for the pre-policy period, shows that the choice of obstetrician-led providers for micro-network 3 in the pre policy period is close to 100%, nearly constant over time. But the average choice of obstetrician-led providers for the other 39 micro-networks are increasing from about 70% to almost 80%.

This will likely bias the estimation results for DID. The coefficient estimated by DID, the first column and the first line for Micro-network 3, $\hat{\tau}^{did} = -0.173$, at the bottom set of results in the Table 3.2, is upward biased. This very likely shows a greater reduction than the true effect.

Figure 3.6 shows the advantage of using the synthetic control method. In this case the synthetic control is generated as an weighted average of a sub-set of the other 39 micro-networks that closely match the observed outcome of the pre-policy period of micro-network 3.

The left panel shows that the pre-policy adjustment is very close, and the right panel depicts the difference between the real and the synthetic control. Given this results it is plausible that the policy had an effect in reducing the use of high structural quality delivery providers in micro-network 3.

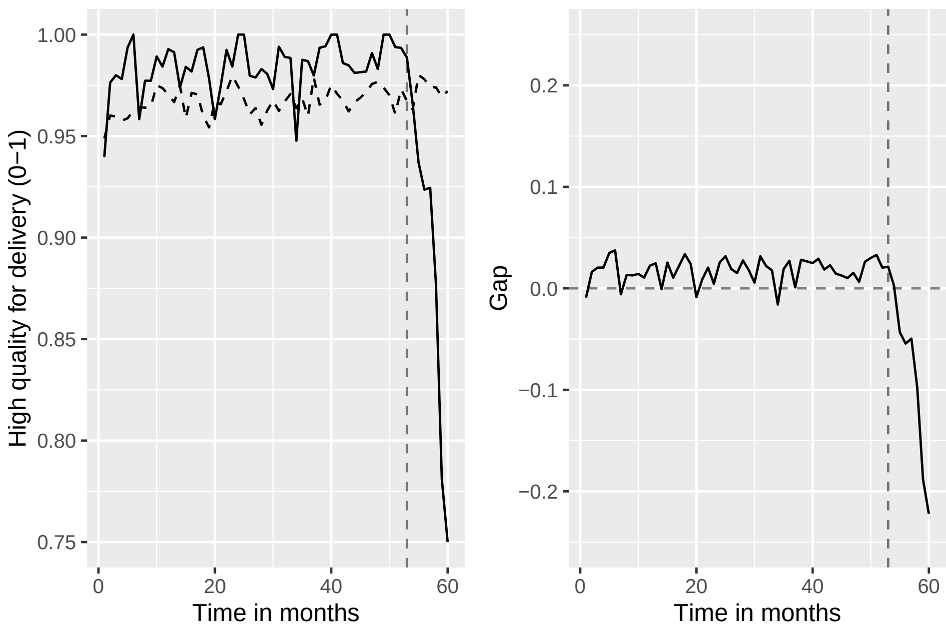

Figure (3.6) Synthetic control results for Micro-network 3: Choice of obstetrician-led provider for child delivery

Note: Left panel: choice of obstetrician-led provider for child delivery in micro-network 3 (bold line) vs. synthetic control (dashed line). Right panel: Gap in choice of obstetrician-led provider for child delivery, actual minus synthetic control. The vertical dashed line signals the time when the new midwife-led maternity unit was implemented, in June 2015.

Figure 3.7 shows the prediction of the placebo test and the estimation of significance based on the distribution of estimated placebo ATTs. The left panel plots for all micro-networks the difference between the outcomes and its synthetic control. For the micro-networks where there was no policy intervention (grey lines) there are no policy effect but only for micro-network 3. The right panel plots the distribution of estimated 'effects' for all micro-networks and the effect for the treated micro-network is an outlier.

I report the numeric estimation for SC in the group of results for micro-network 3 (bottom part of Table 3.2, second column, first line). Synthetic control estimates an effect of $\hat{\tau}^{sc} = -0.093$ with p-value of 0.03. This suggest the policy reduces women's choice of obstetrician-led providers by 9% in micro-network 3.

Figure 3.8, shows the synthetic difference in difference estimation for the same outcome.

SDID combines the strength of both DID and SC. First this generates a synthetic control, the dashed blue line. Then as the match between synthetic control and the observed outcome in the pre-treatment period is not perfect, the method corrects this assuming a parallel shift (red dashed line) from where the effect is evaluated in the post-treatment period (solid red line).

Figure 3.9 shows the prediction of the placebo test for point estimates by synthetic difference in difference based on the distribution of estimated placebo ATTs.

The results for SDID in the group of results for micro-network 3 (bottom part of Table 3.2, third column, first line), shows that synthetic difference in difference estimates an effect of $\hat{\tau}^{sdid} = -0.108$ with p-value (<0.01). This policy reduces women's choice of obstetrician-led providers by 11% in micro-network 3.

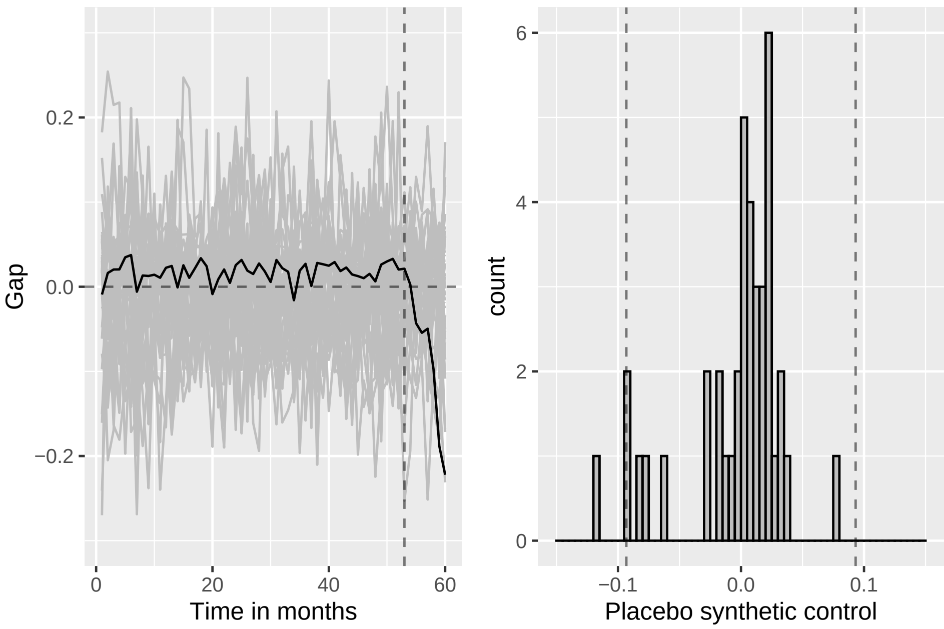

Figure (3.7) Placebo test and significance with synthetic control for micro-network 3: Choice of obstetrician-led providers for child delivery

Note: Left panel: Gap in high structural quality choice for child delivery for micro-network 3 (black line) compared with the placebo test, gaps for the 40 micro-networks of the donor pool (grey lines). Right panel: The distribution of the placebo ATTs of 41 estimations (40 controls and 1 treated). The dashed lines indicate the 95% confidence interval for the distribution of estimated ATT.

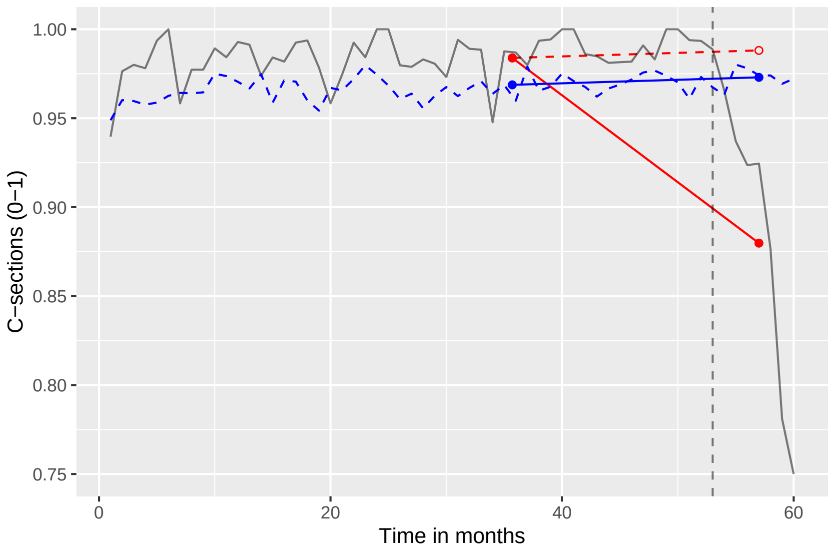

Figure (3.8) Synthetic difference in difference results for Micro-network 3: Choice of obstetrician-led provider for child delivery

Note: The solid grey line is the actual value, the dashed blue line is the synthetic control. The solid blue line is the average of synthetic control. The dashed red line is the synthetic difference-in-difference control, while the solid red line shows the deviation estimated due to the policy. The effect of the policy is estimated by the difference between both red lines in the post-policy period.

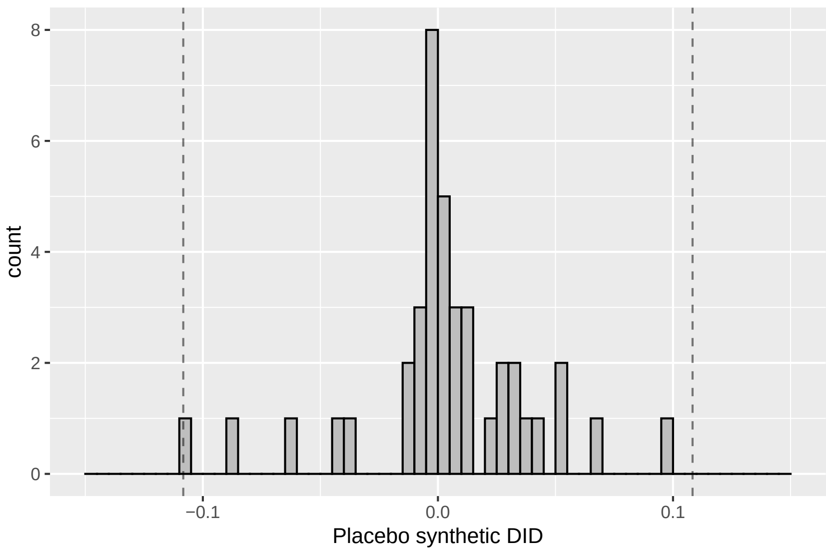

Figure (3.9) Micro-network 3: Distribution of point estimates (placebo test) synthetic difference in difference for choice of obstetrician-led providers for child delivery

Note: The distribution of the placebo ATTs of 41 estimations (40 controls and 1 treated) for SDID point estimates. The dashed lines indicate the proportion of the distribution of estimated ATT that lies inside the 95% confidence interval

Overall, as SDID is consistent in a wider variety of circumstances, I will focus in the third column of Table 3.2 in the remaining of the analysis.

Comparison of effects on quality of care

The first group of nine coefficients in Table 3.2, in the third column, show SDID results for micro-network 1. The policy reduces choice of obstetrician-led providers for child delivery by 12% and increases provider continuity in midwife-led maternity units by 9%. But the policy has no effect on the rate of C-sections, provider continuity of care in obstetrician-led maternity units nor on health outcomes: haemorrhage, sepsis, puerperal infections, perineal laceration or retained placenta and membranes.

The second group of nine coefficients in Table 3.2, in the third column, show SDID results for micro-network 2. The policy increases provider continuity of care in midwife-led maternity units by 5% , but weakly (pvalue < 0.10), although this does not reduce the usage of obstetrician-led providers for child delivery. This suggests that the effects come from women who would have previously chosen antenatal care with providers who do not have child delivery capabilities and now some women choose both antenatal care and child delivery in the midwife-led maternity unit. The policy has no effect on the rate of C-sections nor of these health outcomes: haemorrhage, sepsis, puerperal infections, perineal laceration or retained placenta and membranes. Overall the policy in this micro-network is almost ineffective, with only a weak effect in increasing continuity of care in the midwife-led maternity unit.

The third group of nine coefficients in Table 3.2, in the third column, show SDID results for micro-network 3. The policy has an effect on reducing choice of obstetrician-led providers for child delivery by 11% and reducing the rate of C-sections by 10%, both of them highly significant (p-value <0.01).

The policy increases provider continuity of care in midwife-led maternity units by 5.5% with lower significance (p-value <0.10) but does not affect obstetrician-led continuity of care. The policy also has an impact in the reduction of perineal laceration by 1.3%, but with low significance (p-value<0.10). Finally there is no effect in any of the other health outcomes: haemorrhage, sepsis, infection and retained placenta and membranes.

Overall, the policy in this micro-network is effective in switching the demand from obstetrician-led providers to midwife-led providers, increasing continuity of care in midwife-led maternity units, reducing C-sections and, potentially in improving health outcomes, though these later effects are never statistically significant at the conventional 5% level.

Comparison of effects on quality of care across micro-networks

From the comparison of results across micro-networks it is observed that the policy, ordered from the least to the highest effect, improves one quality of care indicator for micro-network 2, improves two quality of care indicators in micro-network 1 and improves three quality of care indicators in micro-network 3. The policy has an effect in increasing continuity of care in midwife-led maternity units, and this is the only quality of care indicator that is affected by the policy in all micro-networks. And this is the only effect for micro-network 2. The policy switches women's choice from obstetrician-led provider to midwife-led provider in micro-network 1 and 3. This is the only additional effect for micro-network 1. The policy reduces C-section rates and perineal laceration only in micro-network 3, and there is no effect on other health outcomes in any of the three micro-networks.

The reason for the different effects are not due to differences in facilities in the new providers since all of them complying with the requirements of the Health Ministry, but instead to their location relative to other providers.

The first and the second new midwife-led maternity units were opened in micro-networks where there were already another midwife-led maternity units in operation. The difference between them is the distance to the nearest obstetrician-led maternity unit. The first midwife-led maternity unit has an obstetrician-led provider very near and the second further away. The third new midwife-led maternity unit has an obstetrician-led provider very close and there was no other midwife-led maternity unit in the micro-network. This configuration means that nearly all women accessed the obstetrician-led provider with the consequently high access to interventionist procedures, in particular C-sections. Therefore the policy of opening a new midwife-led maternity unit in micro-network 3 has a greater impact than in the other micro-networks.

Micro-network 1 is also close to an obstetrician-led maternity unit, but the potential effect of the policy of opening a new midwife-led maternity unit is reduced due to the presence of a pre-existent midwife-led maternity unit in this micro-network. Micro-network 2 is far from an obstetrician-led maternity unit and in the pre-policy period there was already a midwife-led maternity unit in operation. Therefore the potential benefit of opening a new midwife-led maternity unit is reduced.

This suggests that the potential benefits of a new midwife-led maternity unit comes from two sources: the distance to the nearest obstetrician-led provider and the prior existence of a midwife-led maternity unit in the micro-network. The closer the distance to an obstetrician-led maternity unit the more women are accessing medically intensive procedures, which a new midwife-led maternity unit can potentially improve. The greater the number of midwife-led maternity units in a geographical area means that the marginal benefit to open an additional midwife-led maternity unit is reduced.

3.4.2 Effects on welfare

Table 3.3 presents the conditional logit regression results for equation 3.6. Utility increases with continuity of care and high structural quality provider choice for child delivery but is not affected by structural quality for antenatal care. This is the main difference between conditional logit results in this chapter from those in Chapter 2. In this case the explanation may be because most antenatal care are provided locally and the extra distance involved for choosing antenatal care in high level providers is different in the sample of women in the three micro-networks than that of the overall population.

As expected, distance has a negative impact in utility and women are more sensitive about distances for antenatal care. The coefficients on distance for antenatal care suggests more disutility than for child delivery: women are less willing to travel for antenatal care. The interactions between co-morbidities and distances are positive and negative as some co-morbidities increase willingness to travel for delivery and others reduce it.

Table 3.4 reports the estimated consumer surplus expressed in kilometres. This is the increase expected utility per woman after the implementation of new midwife-led maternity units (equation 3.9) divided by the negative of the coefficient on distance travelled for child deliveries (Table 3.3).

Overall the increase in consumer surplus is equivalent in a reduction of 0.4 km, and there is no statistical difference in gains in consumer surplus between micro-networks. Taking into account that the average distance travelled is 5km this reduction represents about 8% of the distance travelled.

3.4.3 Policy implications

The average time for travelling to give birth in the year 2015 in Lima was about one hour 15 minutes (Instituto Nacional de Estadistica e Informatica del Peru, 2015a). My estimates (Table 3.4) of the average equivalent reduction in distance due to opening of a midwife-led delivery unit implies a reduction of 6 minutes of travel time.

Gowrisankaran et al. (2015), using US data, estimate that increasing one minute in travel time to hospital reduces consumer surplus by $167. Given that the mean income in Virginia in the United States, where this study comes from, is about 18 times that of Lima, this implies that women in Lima value the time saving at about $ 9 dollars per minute. The welfare effect in terms of the increase of consumer surplus is equivalent to $54 per women. Using the annual average number of women of each micro-network in the post-policy period the estimated average annual consumer surplus generated are $71,203, $124,374 and $100,101 for micro-networks 1, 2 and 3.

If I use shadow prices estimated by the Ministry of Economics of Peru, one minute reduction in travel time is equivalent to 0.13 Soles (Ministerio de Economia y Finanzas del Peru, 2012). Using the 2015 purchasing power parity conversion factor (World Bank, 2015) the value of 6 minutes reduction in travel time is $1.25 per woman, given an estimate of consumer surplus that is about 43 times lower. I note however that the Ministry of Economics' valuation is used for transport investment projects and not specifically for accessing health services.

Due to the great divergence in results this monetary evaluation of the utility gain to women using monetary value conversion needs to be treated cautiously.

An alternative is to estimate the cost of the time saving using the cost of investment in building

Table (3.3) Conditional logit choice model results

	(1) Est. β	SE
Continuity of care		
Provider continuity of care	1.880***	(0.037)
Structural quality of providers		
High structural quality provider for child delivery	2.543***	(0.023)
High structural quality provider for antenatal care	0.086	(0.054)
Distances		
Distance (in Km) travelled for delivery	−0.241***	(0.009)
Distance (in Km) travelled for antenatal care	−2.489***	(0.102)
Patient's characteristics interacted with child delivery distance		
Age 1 (< 21 years)	0.020***	(0.005)
Age 2 (21 - 25 years)	0.008	(0.005)
Age 3 (26 - 30 years)	Ref.	
Age 4 (31 - 35 years)	0.006	(0.006)
Age 5 (> 35 years)	0.011*	(0.006)
Delivery before	−0.046***	(0.008)
Length of stay (in days) before delivery	0.009***	(0.001)
Gestational hypertension	0.037***	(0.008)
Pre-eclampsia	−0.015**	(0.007)
Haemorrhage in early pregnancy	0.002	(0.011)
Diabetes mellitus in pregnancy	0.027**	(0.013)
Maternal care for other conditions	0.017*	(0.010)
Multiple gestation	0.040*	(0.020)
Known or suspected malpresentation of fetus	−0.037***	(0.008)
Known or suspected disproportion	−0.036***	(0.007)
Known or suspected abnormality of pelvic organs	−0.007	(0.005)
Known or suspected fetal abnormality and damage	0.089***	(0.018)
Known or suspected fetal problems	−0.050***	(0.007)
Polyhidrammios	−0.042***	(0.013)
Disorders of amniotic fluid and membranes	−0.047***	(0.012)
Premature rupture of membranes	0.002	(0.019)
Placental disorders	0.042***	(0.009)
Placenta praevia	0.016	(0.013)
False labour	0.077***	(0.006)
Prolonged pregnancy	0.021	(0.015)
Infectious and parasitic diseases classifiable elsewhere	0.045*	(0.024)
January	Ref.	
February	−0.016*	(0.010)
March	−0.019**	(0.009)
April	−0.030***	(0.009)
May	−0.023**	(0.009)
June	−0.032***	(0.009)
July	0.006	(0.009)
August	−0.009	(0.009)
September	−0.017*	(0.009)
October	−0.006	(0.009)
November	−0.007	(0.009)
December	−0.007	(0.009)
2011	Ref.	
2012	−0.008	(0.007)
2013	0.024***	(0.006)
2014	0.047***	(0.006)
2015	0.065***	(0.006)
Patient's characteristics interacted with antenatal care distance not reported		
Child deliveries	17,450	
Observations	4,463,261	
Pseudo R^2	0.57	
Log Likelihood	−40717.95	
AIC	81565.89	
BIC	82431.13	

Note: Dependent variable: utility from choices. The coefficients represent marginal utilities but are unique only up to a proportional (scale) transformation. As the interest in the consumer surplus this model is used to predict utilities for each possible choice in women's choice set in the post policy period Continuity of care includes both midwife-led and obstetrician-led continuity of care. Robust standard errors in parenthesis. * p<0.1, ** p<0.05, *** p<0.01. Sample: women in the 3 micro-networks with new midwife-led providers

Table (3.4) Gains in women's welfare by micro-network

	Consumer surplus	SE	P-value	95% confidence interval	
				Lower	Upper
Micro-network 1	0.418	(0.017)	0.000	0.451	0.386
Micro-network 2	0.381	(0.015)	0.000	0.412	0.351
Micro-network 3	0.417	(0.019)	0.000	0.453	0.380
Average	0.401	(0.016)	0.000	0.432	0.370

Note: Consumer surplus expressed as reduction of travel distance for deliveries (in Kilometres). First, I predicted the utilities for each possible choice in women's choice set using the results in Table 3.3. Second, I estimated the log sum of women's utilities in the post policy period. This process was repeated after dropping the three new midwife-led maternity units from women's choice set. Finally, the consumer surplus is estimated as the difference in both utility log sums divided by the negative of the coefficient on distances which implements the formulae in equation 3.9. Standard errors estimated by 1000 bootstrap replications.

these maternity units, and assuming that overall operating costs are not affected as costs such as salaries of staff could be distributed between the maternity units that these women attended before the policy. The three new maternity units cost at shadow prices, the annual equivalent of $1, $2.3 and $1.5 million of dollars respectively (Ministerio de Economia y Finanzas del Peru, 2019) [4].

Assuming that the main benefit comes from consumer surplus alone and using the annual average number of women of each micro-network in the post policy period, for micro-network 1, 2 and 3, each additional minute in saving is generated with an investment of $131, $170 and $142 dollars, respectively. This suggests that the benefits on consumer surplus alone cannot justify the opening of new midwife-led maternity units. But account should also be taken of the cost savings if women switch to midwife-led providers and have more vaginal deliveries which have lower cost than C-sections.

For micro-network 1, there is a reduction in the choice of obstetrician-led providers by 12% and an increase in continuity of care by 9%. In this micro-network, the switching in demand creates benefits with the differential in cost between vaginal deliveries in obstetrician-led providers and vaginal deliveries in midwife-led maternity units, along with the value of continuity of care in midwife-led maternity units. For micro-network 2, in addition to the increase in women's welfare, there is a statistically weak increase in continuity of care by 5.4%.

For micro-network 3 there is a reduction in the choice of obstetrician-led providers by 11%, an increase in continuity of care by 5.5%, a reduction in C-sections by 10% and a reduction in perineal laceration by 1.3%. The evaluation of micro-network 3 is more complex because the reduction of C-sections implies gains in price due to the lower cost of vaginal deliveries in midwife-led maternity units.

My results suggest that investment in new midwife-led maternity units in Lima should be directed to micro-networks that are close to obstetrician-led providers where most women choose these providers and where the C-section rate are higher. Opening new midwife-led maternity units in micro-networks that have a midwife-led maternity unit already running is not likely to

[4] All values are expressed in terms of the year 2015 where all three maternity units were already operating. The maternity unit in micro-network 1 was valued at shadow prices 4.3 million soles in 2009. Although the actual construction and operation time was different, this was equivalent to 6.9 million dollars. I use for this estimation the 2015 purchasing power parity conversion factor (World Bank, 2015), the shadow discount rate of 8% and the 10 years of evaluation horizon officially published by the Ministry of Economics of Peru for public investment projects to convert those values to annual equivalent values. The new maternity units in micro-network 2 and 3 were valued at shadow prices at 9.8 million of Soles in 2014 and at 6.6 million of Soles in 2012 respectively.

be cost effective.

3.5 Discussion and concluding remarks

I show that in Lima the implementation of midwife-led providers has different effects, primarily driven by the location where the new midwife-led maternity unit was opened.

I found that a midwife-led maternity unit increases its potential benefits if it is situated near an obstetrician-led maternity unit and does not compete with another midwife-led maternity unit. In this case women can be reassured that if things go wrong it will be easy for them to access the nearby obstetrician-led maternity unit.

In micro-networks 1 and 2, the policy is actually opening a second midwife-led maternity unit in these micro-networks. Arguably any benefit from midwife-led care was already in place and the marginal benefit from the additional midwife-led maternity unit is less.

Consequently, micro-networks 1 and 2 seems to have lower return to investment because both were implemented in a micro-network where there was already one midwife-led maternity unit in the pre-policy period. In contrast, the midwife-led maternity unit in micro-network 3, was opened close to a obstetrician-led maternity unit where there was no competing midwife-led maternity units.

From the welfare analysis I find that there are gains in consumer surplus for all micro-networks due to an increase in women's choice sets. But the benefits on consumer surplus can hardly justify the investment cost. Policy-makers should be willing to value travel time similar to a high income country financed with taxes from a middle income country.

When ordered from low to high return to investment, in terms of the number of quality of care indicators considered in this chapter, are: micro-network 2, micro-network 1 and micro-network 3.

Micro-network 2 has the lowest return to investment, compared with the other two micro-networks, because it only adds gains in consumer surplus with a weak statistically significant effect of increasing continuity of care in midwife-led maternity units.

For micro-network 1 I find an increase in consumer surplus, a reduction in choice of obstetrician-led providers for child delivery and an increase in continuity of care in midwife-led maternity units. The policy is effective in switching the demand from higher to low structural quality providers.

Generally I am unable to find an effect in the reduction of C-section rates for micro-networks 1 and 2, perhaps because the rate of C-sections where already low prior to the policy and only low risk women access the new midwife-led maternity units and they would not have a C-section even in the obstetrician-led provider.

This contrast with results for micro-network 3 in which, in addition to consumer surplus and other quality of care indicators, I find a considerable reduction in C-sections (by 10%). In micro-network 3 the C-section rates were high previous to the policy maybe because in this micro-network there was only nearly-universal access to the obstetrician-led maternity unit.

Previous studies suggest that C-sections can be reduced with midwife continuity of care (McLachlan et al., 2012), and can also be reduced due to the support that women receive by another woman during birth (Hodnett et al., 2013) and from turning unborn babies from bottom first to head first at the end of pregnancy (Hofmeyr et al., 2015). My results suggest another possibility in the reduction of C-sections than that explored by previous literature namely, the access to midwife-led maternity units for women with high C-section exposure.

From the policy perspective, as there is considerable investment required to open a maternity unit, policy-makers should evaluate if the gains in quality of care justify the investment required to set up these new maternity units.

I argue that in the Peruvian capital context, the implementation of new midwife-led maternity units should be considered potentially in micro-networks where the access to obstetrician units is high but there is no existing midwife-led unit such as in micro-network 3. In geographical areas where the potential for their use is low, opening more midwife-led maternity units does not necessarily improve quality of care.

Appendix A: Additional tables and figures

Table (A3.1) Sensitivity analysis for synthetic control with and with no covariates (base case)

	(1) SC (p-value) with covariates		(2) SC (p-value) no covariates	
Micro-network 1				
Structural quality				
Choice of obstetrician-led providers for child delivery	-0.102	(0.26)	-0.122	(0.01)
Effect on process quality				
C-sections	-0.029	(0.14)	-0.018	(0.59)
Provider continuity of care in midwife-led unit	0.075	(0.19)	0.093	(<0.01)
Provider continuity of care in obstetrician-led unit	0.004	(0.98)	-0.010	(0.72)
Effect on health outcomes				
Haemorrhage	-0.007	(0.16)	0.001	(0.82)
Sepsis	0.000	(0.93)	-0.011	(0.20)
Puerperal infection	-0.010	(0.65)	-0.001	(0.89)
Perineal laceration	-0.003	(0.86)	-0.008	(0.33)
Retained placenta and membranes	-0.011	(0.91)	-0.008	(0.32)
Micro-network 2				
Structural quality				
Choice of obstetrician-led providers for child delivery	-0.005	(0.37)	-0.024	(0.42)
Effect on process quality				
C-sections	-0.006	(0.65)	-0.011	(0.64)
Provider continuity of care in midwife-led unit	0.055	(0.02)	0.054	(0.06)
Provider continuity of care in obstetrician-led unit	-0.004	(0.21)	-0.001	(0.98)
Effect on health outcomes				
Haemorrhage	0.017	(0.37)	-0.001	(0.97)
Sepsis	0.005	(0.77)	-0.006	(0.43)
Puerperal infection	0.002	(0.30)	0.018	(0.20)
Perineal laceration	-0.001	(0.66)	0.003	(0.35)
Retained placenta and membranes	-0.011	(0.66)	0.001	(0.86)
Micro-network 3				
Structural quality				
Choice of obstetrician-led providers for child delivery	-0.108	(0.02)	-0.108	(<0.01)
Effect on process quality				
C-sections	-0.045	(0.81)	-0.102	(<0.01)
Provider continuity of care in midwife-led unit	0.055	(0.02)	0.055	(0.06)
Provider continuity of care in obstetrician-led unit	0.0030	(0.58)	-0.001	(0.99)
Effect on health outcomes				
Haemorrhage	-0.016	(0.05)	-0.001	(0.90)
Sepsis	-0.014	(0.12)	-0.0002	(0.99)
Puerperal infection	-0.021	(0.21)	-0.011	(0.32)
Perineal laceration	-0.001	(0.65)	-0.013	(0.09)
Retained placenta and membranes	-0.001	(0.79)	0.002	(0.84)

Note: The coefficients present the effect of opening new midwife-led maternity units, in each micro-network, on quality of care outcomes. Column 1 presents synthetic control estimation with covariates and column 2 synthetic control with no covariates (base case), p-values based on placebo test fitted with 'synth' stata command.

Chapter 4

The effects of obstetrician workload on C-sections, upcoding and health outcomes

4.1 Introduction

C-section rates are increasing in most countries (Betrán et al., 2016a; Chen, 2013) becoming a global epidemic (Savage, 2000; Lancet, 2018; Visser et al., 2018) and a serious public health problem (Carr and Riesco, 2007; Kaplanoglu et al., 2015; Ajeet and Nandkishore, 2013). Strong evidence of overuse of C-sections is argued (Boerma et al., 2018) leading to an almost consensus that the rising rate is beyond any reasonable justification (Betrán et al., 2018). the World Health Organization recommends performing C-sections only for medically indicated reasons (World Health Organization, 2015).

In this chapter I argue that when there is a greater obstetricians to delivery ratio on a given maternity unit the C-section rate is greater and that obstetricians upcode co-morbidities to justify their decision.

As the number of obstetricians on duty increases the outcomes for any given procedure are likely to improve. But if an increase in the number of obstetricians changes the mix of procedures, increasing the likelihood of C-sections, this may worsen outcomes. The effect on the outcomes for all deliveries on average is thus unclear.

This chapter investigates the effect of an increase in the ratio of obstetricians/child deliveries on the probability of a woman having a C-section, the use of co-morbidity codes that justify C-sections, and on maternal health outcomes.

There is evidence that obstetricians change their behaviour by day of the week or time of day (Burns et al., 1995; Gans et al., 2007; Costa-Ramón et al., 2018; Arrieta and García Prado, 2016). This is due to the fact that C-sections are easy to perform and more predictable in the use of time. There is also evidence for obstetricians' upcoding of co-morbidities in women's clinical records (Spetz et al., 2001).

This chapter contributes to the literature in a number of ways. Previous literature focuses on the analysis of increasing rates of C-sections at the provider level (Kozhimannil et al., 2013; Bragg et al., 2010; Lee et al., 2013; Wehberg et al., 2018; Sinnott et al., 2016) that accounts for between-provider variation of volume of delivery on C-sections but not accounting for the number of obstetricians. Studies that use daily variation, separately address the number of obstetricians (Zbiri et al., 2018) or the volume of child delivery (Snowden et al., 2013) on C-sections, but not the number of obstetricians and child deliveries together.

In contrast, I believe this is the first study that combines daily variation in volume together with daily variation in the number of obstetricians within each provider to examine their effect on the probability of women having a C-section, upcoding and health outcomes.

I develop a simple theoretical model where obstetricians value women's health, but also derive personal utility from performing C-section. Obstetricians may prefer C-sections because they are easy to perform and more predictable in the use of time[1]. They recognise that performing C-sections in healthy women or vaginal delivery in high risk women could result in a poor health outcome. However, for women with intermediate health risk, obstetricians benefit from C-sections, meaning that their decision to perform a C-section will vary according to the maternity unit's surgical capacity available on a given day.

In this context, when the number of child deliveries is lower than the maternal unit's surgical capacity, obstetricians perform all the C-sections they can justify. When the number of women increases, surpassing the maternity unit's surgical capacity, obstetricians select progressively higher risk women for C-sections and consequently reduce the rate of C-sections. Obstetricians are thus more likely to upcode co-morbidities when the obstetrician/delivery ratio increases.

Due to possible endogeneity in the number of obstetricians per day, since the number of obstetricians can be endogenously determined by the number of C-sections planned, I use the fact that no elective (planned) C-Sections take place on Sundays. The number of obstetricians per Sunday varies due to rota scheduling and is exogenous because it is determined for each Sunday in advance, varying with the expected volume of delivery (and expected number of C-sections and vaginal deliveries). But the on-the-date realisation of the number of women who show up to the maternity unit could be randomly higher or lower than expected. This generates a random variation in the number of delivery relative to the number of obstetricians on duty.

The remainder of this chapter is structured as follows: Section 4.2 briefly summarises and discusses the previous literature, especially papers on volume and health outcomes; in section 4.3 I formalise the theoretical model and in section 4.4 the empirical strategy; section 4.5 presents the data and its descriptive statistics; section 4.6 presents the results and section 4.7 the discussion and conclusion.

4.2 Selective literature review

The research in this chapter is related to three fields in the literature: physician-induced demand, the volume-outcomes relationship, and the capacity and outcomes relationship.

4.2.1 Physician-induced demand

The physician-induced demand framework, generally attributed to Evans (1974) is defined by McGuire (2000, p.504): "*Physician-induced demand (PID) exists when the physician influences a patient's demand for care against the physician's interpretation of the best interest of the patient*". There are several channels for this studied in the literature; physicians can respond to changes in

[1]C-sections on average take 30 minutes while vaginal deliveries in the first pregnancy will typically be 8 hours or more (Penna and Arulkumaran, 2003).

physician-to-population ratios (Cromwell and Mitchell, 1986; Fuchs, 1978; Léonard et al., 2009), because of defensive medicine (Danzon, 2000; Kessler, 2017) and physicians referring patients to their own services (Mitchell and Sass, 1995; Scherer, 2000). Physician convenience is also noted as a motive (Johnson, 2014).

In general, the evidence suggests that surgeon-rich geographical areas have higher numbers of surgeries (Cromwell and Mitchell, 1986; Fuchs, 1978; Léonard et al., 2009), that C-section rates varies across hospitals, and that there is an unexplained between-hospital variation in C-sections (Lee et al., 2013; Wehberg et al., 2018; Sinnott et al., 2016).

I investigate whether this phenomenon also occurs within the same hospital, namely if the probability of C-section varies with the number obstetricians on duty relative to the observed volume of deliveries.

It is argued that obstetricians' valuation of leisure time leads them to perform C-sections during the day from 6am to 6pm or on Fridays (Burns et al., 1995), and, more specifically, 6pm-8pm near to dinner hours and on Fridays from 3pm to 9pm, called "Friday rush effect" (Gans et al., 2007); the early hours of the night (from 11pm to 4am) (Costa-Ramón et al., 2018), and in the afternoons in small and medium sized hospitals (Arrieta and García Prado, 2016). Obstetricians can also conveniently move the volume of deliveries, likely by planned C-sections, to free up time around their annual professional conferences (Gans et al., 2007).

Previous studies have found that obstetricians change their behaviour with performing C-sections on Fridays (Burns et al., 1995; Gans et al., 2007), and more generally, for performing this procedure on weekdays rather than on weekends (Halla et al., 2016).

This chapter contributes new evidence on the effect of the ratio of obstetricians to deliveries on the C-section rate using data from Sundays where, in Peru, all C-sections are non-elective. Thus the relationship between the ratio of obstetricians/child deliveries and C-section rates is likely to be causal.

Upcoding has also been studying in the context of physician-induced demand, related to price differences between procedures with and without complications in general (Januleviciute et al., 2016), and for C-sections (Di Giacomo et al., 2017). There is also evidence of upcoding by obstetricians to justify C-sections during day hours (Spetz et al., 2001). I investigate if there is upcoding when there is less demand pressure on obstetricians leading them to increase the probability of C-sections for women at intermediate risk.

4.2.2 Volume-outcomes relationship

The relationship between the volume of treatment and health outcomes has received vast attention since the pioneering work of Luft et al. (1979) but results are mixed. Some find that variation in quality, not volume, across hospitals explains the variation of health outcomes between providers (Hamilton and Hamilton, 1997; Hamilton and Ho, 1998; Barker et al., 2011) while others argue that there is a genuine effect of volume (Hentschker and Mennicken, 2018).

For C-sections Kyser et al. (2012) found higher rates of complications in low-volume as well as high-volume hospitals, in contrast with medium-volume hospitals. However, others argue that this effect is only in lower-volume hospitals (Janakiraman et al., 2011). Nippita et al. (2015) found that the between-hospital variation of C-section rates had no effect on women's health outcomes, suggesting that it is possible to reduce them without affecting maternal health outcomes . LeFevre (1992) find that the volume of deliveries per physician does not have an effect on perinatal death and neonatal death, but they measure workload as deliveries per year per physicians, and their outcomes are relatively rare.

The closest research related to the effect of the number of obstetricians on C-sections argues that an increase in obstetricians reduces C-section rates (Zbiri et al., 2018). This is clearly in contrast to my findings, and might be because they use the annual average full-time equivalent weekly hours, rather than the daily number of obstetricians. Snowden et al. (2013) use daily variation in volume, using a binary variable to define high and low volume. They found that a high volume of deliveries on weekends are associated with a low risk of C-section. This chapter adds to the evidence with the use of the ratio number of obstetricians/child deliveries, and I also control for the effect of a different number of obstetricians on duty per day.

Clapp et al. (2014) use a measure of volume of deliveries and obstetricians together, and found that low delivery volume obstetricians, estimated as annual deliveries, increases the risk of C-sections. They also find that obstetricians behave differently when their volume of delivery changes arguing that the actual annual volume, rather than the volume of a previous year, is the determinant of a C-section being performed.

Using high frequency daily variation in volume, I go beyond the classical debate in the volume-outcome relationship (Luft et al., 1987) whether volume can improve outcome by the channel of learning-by-practice or whether high quality providers attract more patients. I argue that high frequency variation in volume is not related to learning-by-practice, i.e. obstetricians are not improving their skills on the basis of a sudden daily increase of child deliveries on a maternity unit. This is because a variation in one day is hardly related to the acquisition of skills that can be reflected in health outcomes on the very same day.

4.2.3 Capacity and outcomes relationship

Some literature that examines the effect of capacity on health outcomes uses between-hospital variation of demand and some uses within-hospital variation of demand. Here I focus on studies that consider the latter because this controls for the fact that patients can choose providers according to their health status or because of hospital reputation (Cutler et al., 2004).

Evans and Kim (2006) examine the variation of shocks on demand for Fridays and Saturdays and how this affects the outcomes of patients admitted on Thursdays, finding a small increase in the probability of readmission for Thursday patients. Schwierz et al. (2012) studied 423 departments in 72 acute German hospitals and examines the effect of unexpected demand on emergency readmissions. The unexpected demand was estimated by a regression method that includes department fixed effects, hospital fixed effects, monthly seasonality, day of the week and public holidays. The shock in demand was defined by the difference between the predicted residuals and the patients counts in each department. They found that shocks in demand does not affect emergency readmissions.

Jiang and Pacheco (2014) use a regression method, similar to Schwierz et al. (2012), and examine the effect of a shock of demand in disease chapters that group similar co-morbidities. Shocks in demand increases length of stay, and acute readmission within 30 days of discharge.

In contrast to these studies I improve the identification strategy in a number of ways. First, I consider variations of volume of demand on Sundays when there are no planned C-sections. This has the advantage of avoiding elective C-sections that can be planned for weekdays according to the scheduled number of physicians on duty on those days.

Second, I also use information about the number of obstetricians on duty per day. Although the number of staff for any particular day may be planned in advance according to the expected deliveries, it may vary on any given day of the week due to annual leave, staff sickness or the schedules. For example, in Peru five staff are required for covering 24 hours and 7 days of care per week. Then if there are 15 staff there will be three staff per day every day of the week. But if there are 12 staff some days there will be three and some others only two staff. Therefore some Sundays there will be a variation on staff due to rota schedule.

Third, I use the variation in the ratio of obstetrician to actual child deliveries instead of using a predicted, and subject to estimation errors, volume of demand.

Fourth, my dataset allows for controlling obstetrician's fixed effect. This has the advantage that staff preferences, skills and experience can be held constant. Then the same obstetrician can react differently to variations in the workload on two different days.

4.3 Theoretical model

This sections sketches a theoretical framework that explains how the ratio of obstetricians/child deliveries can affect the decision to perform C-sections and upcoding.

First, for a woman $i = 1, ..., I$ I define her heath status as

$$h_i = h(X_i) \tag{4.1}$$

where $0 \leq h_i \leq 1$ represents the underlying women's C-section risk, X_i is a vector of morbidities that influence a woman's C-section risk. The population of women has a distribution on this range $F(h)$. The rate of C-section if C-sections are offered to all women with morbidity higher than h_i is $r = 1 - F(h(X_i))$.

I assume that the general risk of bad outcomes varies by procedure and $\hat{h}_i$. The benefits of vaginal delivery are greater than a C-section for healthy women with low $\hat{h}_i$ and conversely C-sections reduce the bad outcomes risk for women with lots of co-morbidities. I assume there is a unique $\hat{h}^0 \in \{0, 1\}$ where the unconstrained perfect-agent obstetrician will perform C-sections for all women with C-section risk higher than h^0 and vaginal deliveries for women with health status lower than h^0.

Figure 4.1 plots the distribution of the underlying C-section risk in the population of women, the potential outcome of performing vaginal deliveries ($O^V(h)$) and C-sections ($O^C(h)$) and the C-section rate in the case of an obstetrician acting as perfect agent (r^0) when there are no constraints on the choice of procedure.

More generally, the obstetrician also has a personal benefit from C-sections procedure, and prefers performing a C-section rather than vaginal delivery in all cases, excepting when it is clearly evident that his decision can be challenged. Thus will wish to perform C-sections for $h_i < h^0$.

Every obstetrician has a different ability to defend their decisions; this could depend on his experience, prestige, surgical skills, or past outcomes. Let h_j^{min} be the lower threshold where the obstetrician is comfortable defending his diagnosis and decision to perform C-sections on ethical committees or eventually before a judge in a complaint case. The maximum rate of C-sections of the representative obstetrician is $r_j^{max} = 1 - F(h_j^{min})$. So the obstetrician will wish to perform a C-section on any woman that has a C-section risk in the range $h_j^{min} < h_i$.

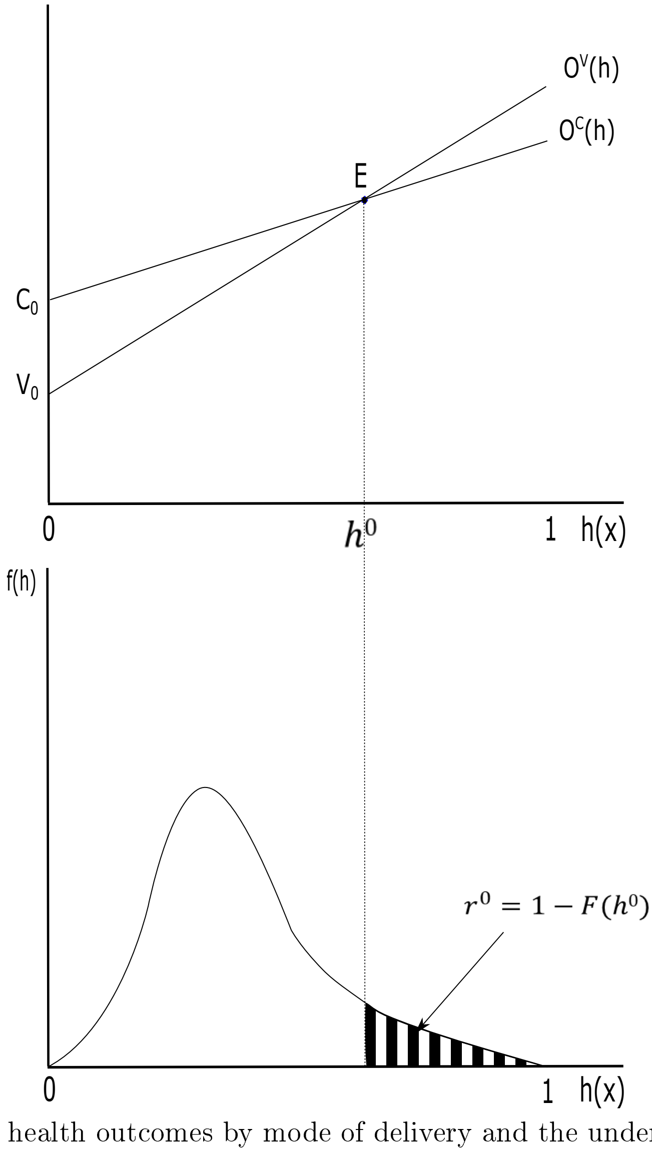

Figure (4.1) Potential health outcomes by mode of delivery and the underlying C-section rate

Figure 4.2 shows women's health status range where obstetricians act by convenience and the potential health outcomes in terms of complications that are acceptable by the obstetrician.

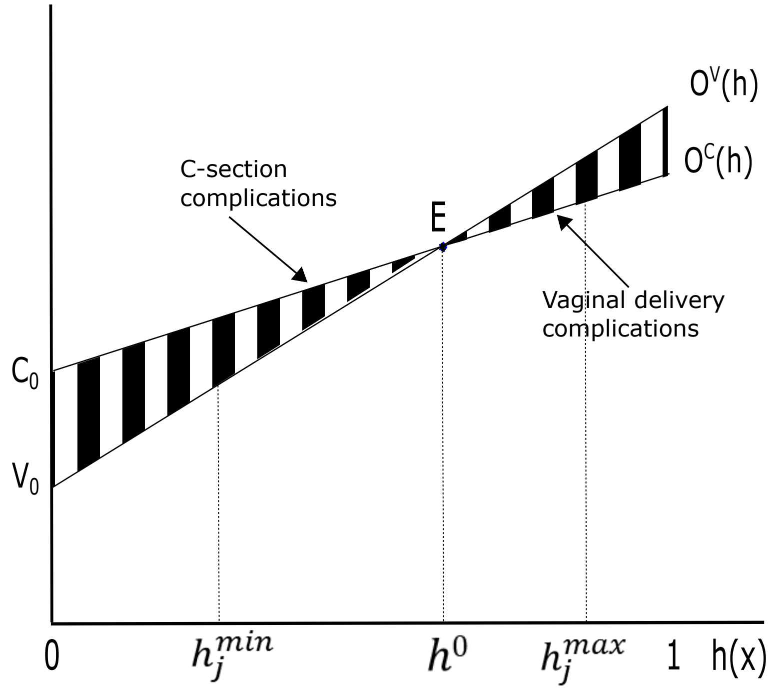

Figure (4.2) Women's health status range where obstetricians acts by convenience and potential health outcomes

The obstetrician can justify the choice of procedure by their recording of the patient's co-morbidities. But the more healthy the woman the more difficult it is to code a woman as with having high risk of co-morbidities. So the further h_j is below h^0 the more likely is up-coding.

I define P_{kt} as the ratio between the number of obstetricians on duty to the volume of women that show up to every maternity unit k at time t.

On Sundays the number of obstetricians for each maternity unit are determined in advance in the absence of scheduled surgeries according to the expected volume of deliveries, including the number of C-sections expected, and so the surgical capacity is also determined in advance. On busy days when the realisation of the volume of deliveries surpasses the number of women expected, obstetricians will choose higher risk women for surgery decreasing the rate of C-sections, so that volume has a negative effect on the maternity unit's C-section rate. If there are more obstetricians on duty relative to the number of deliveries they will increase the C-section rate, and obstetricians will be choosing progressively lower risk women for the operating theatre. So the C-section rate of the maternity unit will increase with P_{kt}. I assume that there is a lower limit on P_{kt} such that all women with $h_i > h_j^{max}$ will receive a C-section. The obstetrician will perform a C-section for women with $h_i \in \{h_j^{min}, h_j^{max}\}$ if capacity is above the lower limit. Women with $h_i < h_j^{min}$ will always have vaginal delivery. The obstetrician will upcode diagnoses for women with $h \in \{h_j^{min}, h^0\}$ who have a C-section.

The figure 4.3 summarises the stylised decision rule for performing C-sections and up-coding according women's health status.

The C-section rate in a given maternity unit will depend on the volume of women that show up on that day and the number of obstetricians on duty. An increase in P_{kt} due to an increase in

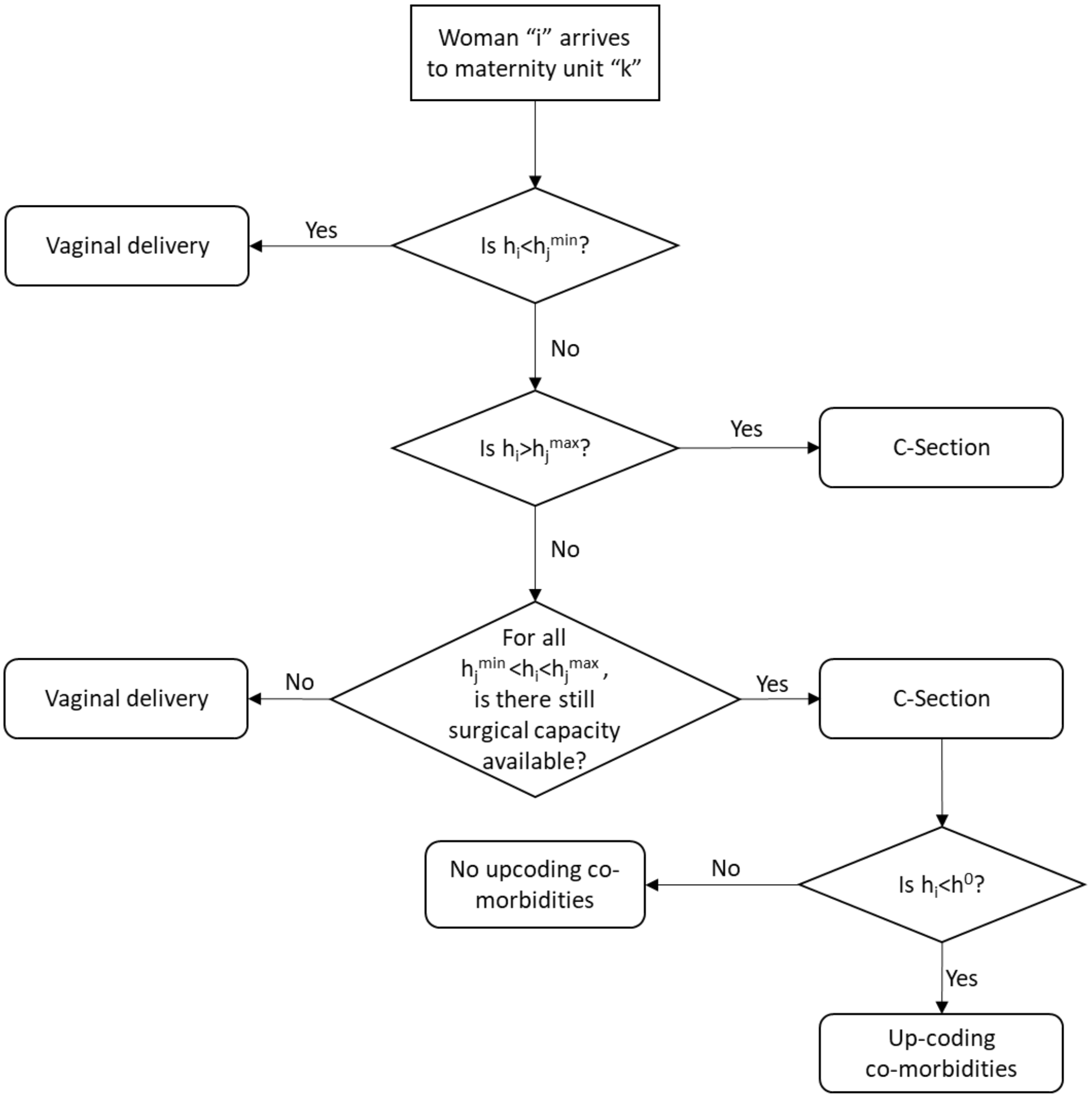

Figure (4.3) Decision rule for C-sections up-coding according to maternity unit's surgical capacity obstetricians or a decrease in the volume of delivery, will improve health outcomes, conditional on delivery method. But on the other hand it will increase the C-section rate, potentially worsening outcomes for women with $h_i < h^0$. Thus an increase in P_{kt} could worsen or improve health outcomes on average.

4.4 Empirical specification

I follow Currie and MacLeod (2017) for estimating women's C-section risk h_i as a function of co-morbidities. I fit the C-section risk exposure per women $i = 1, ..., I$ using only antenatal care co-morbidities with the following pooled logistic regression for women on all Sundays in all delivery providers.

$$h_i = X_i^{anc'}\beta + \epsilon_i \tag{4.2}$$

Then I predict $\hat{h}_i$: C-section risk based on previous co-morbidities. P_{kt} does not affect $\hat{\beta}$ and hence $\hat{h}_i$ because on average women's first antenatal care choice was made 100 days before delivery and most of them are recorded by local providers that are different than the delivery provider. I include all co-morbidities recorded in the antenatal care period in X_i^{anc}. The vector X_i^{anc} includes a constant term in all regressions in this chapter.

4.4.1 Number of obstetricians/volume of delivery and C-section rates

The interest is in the effect of obstetricians/child deliveries per day (P_{kt}) in a maternity unit on women's C-section risk. So the equation of interest for women $i = 1, .., I$ on maternity unit $k = 1, .., K$ at the t'th Sunday is

$$CS_{ikt} = \beta_P P_{kt} + X_{ikt}^{anc'}\beta_x + \gamma_k + \gamma_j + \epsilon_{ikt} \tag{4.3}$$

Equation (4.3) is estimated as a Linear Probability Model (LPM). Angrist and Pischke (2009) discuss extensively the advantage of using linear probability model instead of non-linear models, such as probit. For non-linear models there are decisions to make such as assumptions about the distribution of the errors, derivatives versus finite differences, among others. But critically in this chapter the use of large quantities of dummies for provider fixed effects, which is crucial in the identification strategy, and for obstetrician fixed effects to assess changes in behaviour of the same obstetrician, makes hard to fit a non-linear model like logit or probit due to the incidental parameters problem that, likely, biases the estimation (Greene, 2002). LPM can be biased when probabilities are small but as the C-section rate is 31% LPM and logit or probit models would yield similar results in the absence of having to include provider fixed effects. Note that in the logistic specification for C-section risk in (4.2) I do not include any fixed effects.

$CS_{ikt} \in \{0, 1\}$ is equal to 1 if woman i at maternity unit k at day t has a C-section and 0 otherwise. P_{kt} is the number of obstetricians on maternity unit k at day t divided by the number of women that show up on maternity unit k at day t. X_{ikt}^{anc} contains a vector of patient's co-morbidities registered in the antenatal care period.

I include maternity unit dummies ,γ_k, to control for the fact that women can choose hospitals due to their particular characteristics. For example there are some facilities that have higher structural quality so they might attract higher risk pregnancies. I also include staff dummies

γ_j that capture obstetricians' fixed effects[2], to ensure that while the obstetrician may behave differently on two Sundays due to the demand and staffing variation, this staff fixed effect holds preferences, knowledge and skills constant. ϵ_{ijt} is the error term.

For investigating the heterogeneity for women's C-section risk, I fit the following full quadratic specification

$$\begin{aligned} CS_{ikt} &= \beta_P P_{kt} + +\beta_{P0} P_{kt}^2 + \beta_{P1} P_{kt} * \hat{h}_i + \beta_{P2} P_{kt}^2 * \hat{h}_i \\ &+ \beta_{P3} P_{kt} * \hat{h}_i^2 + \beta_{P4} P_{kt}^2 * \hat{h}_i^2 + X_{ikt}^{anc'} \beta_x + \gamma_k + \gamma_j + \epsilon_{ikt} \end{aligned} \tag{4.4}$$

I add the full quadratic iteration between the ratio P_{kt} and the predicted women's C-section risk $\hat{h}_i$ from equation (4.2). This is because in the theoretical model I show that the representative obstetrician performs C-sections for convenience in women that are in the intermediate region of women's C-section risk. For women who are healthy, obstetricians will not be able to justify C-sections, and women whose heath status is poor will have a C-section anyway.

4.4.2 Number of obstetricians/volume of delivery and upcoding

As discussed in the theoretical part, obstetricians who prefer C-sections need to justify their decision, so the following equation captures the women's exposure to up-coding for each candidate upcoding justification variable X^{up} at the time of child delivery.

$$X_{ikt}^{up} = \beta_P P_{kt} + X_{ikt}^{anc'} \beta_x + \gamma_k + \gamma_j + \zeta_{ikt} \tag{4.5}$$

The vector X_i^{up} takes values $\in \{0,1\}$ for all $x^{up} = 1, ..., X$, as the obstetrician records the presence of these co-morbidities at delivery.

The co-morbidities used to justify a C-section should be independent of the number of obstetricians on duty and the volume of child deliveries on a given Sunday.

I include the vector of co-morbidities of the antenatal care period, X^{anc}, to control for the woman's 'true' health as antenatal morbidities can not be upcoded as a consequence of a C-section and the decision to provide a C-setion which then requires justification via upcoding of delivery morbidities depends on X^{anc}. To allow for the fact that upcoding is more likely for intermediate levels of X^{anc} I also estimate the quadratic specification.

$$\begin{aligned} X_{ikt}^{up} &= \beta_P P_{kt} + \beta_{P0} P_{kt}^2 + \beta_{P1} P_{kt} * \hat{h}_i + \beta_{P2} P_{kt}^2 * \hat{h}_i \\ &+ \beta_{P3} P_{kt} * \hat{h}_i^2 + \beta_{P4} P_{kt}^2 * \hat{h}_i^2 + X_{ikt}^{anc'} \beta_x + \gamma_k + \gamma_j + \epsilon_{ikt} \end{aligned} \tag{4.6}$$

4.4.3 Number of obstetricians/volume and health outcomes

I specify the following equation to examine the effect of the ratio of obstetricians/child deliveries on health outcomes:

$$y_{ikt} = \beta_P P_{kt} + X_{ikt}^{anc'} \beta_x + \gamma_k + \gamma_j + \zeta_{ikt} \tag{4.7}$$

[2] Obstetricians move between providers so that providers effects are identified.

The vector y_{ikt} are variables for delivery complications. P_{kt} has two effects on health outcomes, a direct effect via quality of care improves health outcomes, conditional on the procedure, and the indirect effect on the mix of procedures (vaginal versus C-sections). The overall effect is captured by β_P. Chapter 5 focusses on the effect of C-section on health outcomes, and doing so will provide the direction of the indirect effect of P_{kt} on health outcomes: the effect of C-section versus vaginal delivery.

The specification with predicted C-section risk's full quadratic iteration with the ratio obstetricians/child deliveries variable is:

$$\begin{aligned} y_{ikt} &= \beta_P P_{kt} + \beta_{P0} P_{kt}^2 + \beta_{P1} P_{kt} * \hat{h}_i + \beta_{P2} P_{kt}^2 * \hat{h}_i \\ &\quad + \beta_{P3} P_{kt} * \hat{h}_i^2 + \beta_{P4} P_{kt}^2 * \hat{h}_i^2 + X_{ikt}^{anc'} \beta_x + \gamma_k + \gamma_j + \epsilon_{ikt} \end{aligned} \tag{4.8}$$

Additionally, to estimate the effect of the ratio obstetricians/child deliveries on health outcomes on obstetrician-led providers and on midwife-led providers, I estimate the following specification:

$$\begin{aligned} y_{ikt} &= \beta_P P_{kt} + \beta_{O1} P_{kt} * O_k + \beta_{O2} P_{kt} * \hat{h}_i * O_k + \beta_{P0} P_{kt}^2 + \beta_{P1} P_{kt} * \hat{h}_i \\ &\quad + \beta_{P2} P_{kt}^2 * \hat{h}_i + \beta_{P3} P_{kt} * \hat{h}_i^2 + \beta_{P4} P_{kt}^2 * \hat{h}_i^2 + X_{ikt}^{anc'} \beta_x + \gamma_k + \gamma_j + \epsilon_{ikt} \end{aligned} \tag{4.9}$$

Where $O_k \in \{0, 1\}$ is an indicator for whether provider k is an obstetrician-led provider or a midwife-led provider. This variable allows to distinguish the effect of the ratio obstetricians/child deliveries on the 14 obstetrician-led providers considered in the analytical sample 1 from the effect of this ratio on the 36 midwife-led providers, where it is not possible to perform C-sections, because they have no operating theatre but could have obstetricians.

All specifications are estimated using a linear probability model by ordinary least squares on the sub-sample of deliveries on Sundays. For the effect of the ratio of obstetrician per woman on C-sections and on up-coding of co-morbidities the sub-sample of 14 obstetrician maternity units with C-section capabilities are used, while for the effect on health outcomes I use all 50 maternity units.

4.5 Data and descriptive statistics

4.5.1 Source and variables

I use administrative data from the Peruvian public health insurance program in 50 maternity units. The details are described in the institutional background explained in the introduction of this thesis. From the 317,305 cleaned observations on child deliveries I identify 31,754 observations on Sundays in 14 maternity units which have operating theatre and so able to perform C-sections. I use this sample to examine the effect of obstetrician/deliveries on C-sections and upcoding.

To study the effect of capacity on health outcomes, I use deliveries on Sundays on all 50 maternity units (39,477 observations). This to capture the overall effect of the ratio obstetricians/child deliveries on health outcomes, rather than only on providers with operating theatre where C-sections can be performed.

For upcoding, Spetz et al. (2001) identify three co-morbidities recorded at delivery that could be upcoded to justify performing C-sections: foetal distress, prolonged labour, and other "dysfunctional" labour. I identify four possible code candidates for upcoding, two for the mother and two for the baby:

- Prolonged pregnancy (ICD code O48)
- Maternal pelvic abnormality (O34 and O65)
- Foetal stress [distress] (O68)
- Umbilical cord complications (O69)

National guidelines in maternity care recommends performing C-sections in the case of prolonged pregnancies. The national guidelines recognises that the ultrasound scan has a margin of error directly related to the length of pregnancy: errors that span from three to five days in the first trimester of pregnancy, 1 week between the 12-20 weeks of pregnancy, 2-3 weeks between the 20-30 weeks of pregnancy and three weeks after the 30 weeks of pregnancy (Instituto Nacional Materno Perinatal, 2010). This means that the obstetrician, at the time of delivery, has discretion in regarding recording of prolonged pregnancy.

In maternal pelvic abnormality I include two codes, O34 Maternal care for known or suspected abnormality of pelvic organs, and O65 Obstructed labour due to maternal pelvic abnormality. Both of them are very broad categories that include scaring from previous C-sections, cervical incompetence, and generally contracted pelvis, among others. There is no auxiliary test for verifying these conditions. The reason why I include this group as candidates for upcoding is due to the recommendation to perform C-sections in such cases (Ministerio de Salud del Peru, 2007).

For the baby, the definition of foetal stress is recognised as "imprecise" and "unspecified", the most reliable test to identify foetal stress is the use of foetal capillary blood sampling (Instituto Nacional Materno Perinatal, 2010), but this can only be done when there is a dilatation of more than 3-4 cm and ultrasound again is of little help.

Another code strongly related to C-sections is umbilical cord complications, where this can cause foetal stress and it is also difficult to verify. So obstetricians can use these codes, mainly based on their clinical judgement.

I also perform a placebo test for upcoding using diagnoses that are not used to justify C-sections. This is because of the possibility that a higher ratio of obstetricians/child deliveries can improve diagnoses due to the available time per woman, and in this case the observed rise in the use of diagnostic codes should not be considered as upcoding but as an improvement in diagnosis.

For the placebo test I use diabetes mellitus in pregnancy because, although this diagnosis can eventually lead to justifying a C-section it is highly specific in its diagnostics that uses a laboratory test and requires women to be fasting for at least 8 hours. Then if the number of obstetricians on duty improves the diagnostic procedure it should be expected that more women can be screened for previously undetected cases of diabetes. Furthermore, the national guidelines state that there is danger in not diagnosing this co-morbidity (Instituto Nacional Materno Perinatal, 2010).

Information on maternal outcomes is based on data from the time of the delivery up to 28 days after discharge, using dummy variables at the presence of each complication per woman. The diagnoses are classified into six groups, according to their severity and frequency:

- Maternal death (ICD codes O95 and O96)
- Postpartum haemorrhage (O72)
- Puerperal sepsis (O85)
- Other puerperal infections (O86)
- Perineal laceration of second, third and fourth degree (O70.1, O70.2 and O70.3)
- Retained placenta and membranes (O73)

I use actual maternal death as the first maternal health outcome in this study. This differs from other studies, where for example, Sandall et al. (2018) use severe acute maternal morbidity (SAMM) which includes obstetric shock, cardiac arrest, acute renal failure and assisted ventilation as proxies of maternal mortality.

Apart from maternal death, I include its main causes which are, in order of importance, haemorrhage, sepsis, and infections (Say et al., 2014; Khan et al., 2006). I include perineal laceration in the analysis mainly for comparative reasons because it was used in previous medical (Villar et al., 2006) and economic literature (Johnson and Rehavi, 2016; Card et al., 2019). Retained placenta and membranes are included as they are a quality of care indicator related to the delivery technique and the use of medication (Weeks, 2008) which can be improved if the number of obstetricians per woman increases.

It was not possible to link mothers to babies due to anonymised ID, so I do not evaluate the effect of C-sections on child health outcomes.

4.5.2 Descriptive Statistics

Table 4.1 presents the descriptive statistics for the analyses on the effect of capacity on C-sections and upcoding (analytical sample 1) and the effect of capacity on health outcomes (analytical sample 2). The first half of the table contains descriptive statistics and difference in means for analytical sample 1 which includes information on 14 providers with operating theatres. In this sub-sample the C-section rate is about 31% and the ratio obstetricians/child deliveries is 0.44.

I report means, standard deviation and difference in means for four suspected candidate variables for upcoding and the placebo for upcoding variable: prolonged pregnancy is present in 2.5% of C-sections, maternal pelvic abnormality in 31%, fetal stress in 13%, umbilical cord complication in 4.6% and diabetes mellitus in 0.4%. The presence of these codes in vaginal delivery procedures are few compared with C-sections and the difference in means are, respectively, 1.6%, 29.5%, 11.8%, 3.5% and 0.2%, all of them statistically significant.

The second half of the table contains descriptive statistics and difference in means for analytical sample 2, which includes information on 50 providers. This is because the main focus is on the effect of capacity on health outcomes, thus including information on all providers rather than restricting for providers with surgical capacity is desirable. The rate of C-sections in this sample are 25% because I also include 36 providers with only vaginal deliveries because, although they have obstetricians, they do not have an operating theatre. The rate of obstetricians/child deliveries is also lower 0.36.

The difference in means for maternal death (0.03%) haemorrhage (2.6%), sepsis (1.5%) and puerperal infections (2.8%) signals that there are more of these cases with C-sections than for vaginal deliveries. On the other hand, the difference in means for perineal laceration is -0.7%

Table (4.1) Outcomes: means, standard deviations and difference in means test

	Overall	C-sections	Vaginal delivery	Diff. means
ANALYTICAL SAMPLE 1				
Variable of interest				
C-section	0.3099			
	(0.462)			
Ratio obstetricians/child deliveries	0.4377			
	(0.199)			
Number of obstetricians on duty per maternity unit	5.6713			
	(4.066)			
Volume of child deliveries per maternity unit	14.1187			
	(9.372)			
Upcoding variables				
Prolonged pregnancy	0.0138	0.0250	0.0088	0.0162***
	(0.117)	(0.156)	(0.093)	
Maternal pelvic abnormality	0.1068	0.3104	0.0154	0.2950***
	(0.309)	(0.463)	(0.123)	
Foetal stress [distress]	0.0443	0.1257	0.0078	0.1179***
	(0.206)	(0.332)	(0.088)	
Umbilical cord complications	0.0222	0.0462	0.0114	0.0349***
	(0.147)	(0.210)	(0.106)	
Diabetes mellitus in pregnancy	0.0026	0.0043	0.0019	0.0024***
	(0.051)	(0.065)	(0.044)	
Observations	31754	9842	21912	31754
ANALYTICAL SAMPLE 2				
Variable of interest				
C-section	0.2493			
	(0.433)			
Ratio obstetricians/child deliveries	0.3582			
	(0.249)			
Number of obstetricians on duty per maternity unit	4.5748			
	(4.273)			
Volume of child deliveries per maternity unit	11.8294			
	(9.625)			
Outcome variables				
Maternal death	0.0002	0.0004	0.0001	0.0003**
	(0.012)	(0.020)	(0.008)	
Postpartum haemorrhage	0.0170	0.0369	0.0104	0.0265***
	(0.129)	(0.188)	(0.101)	
Puerperal sepsis	0.0079	0.0193	0.0041	0.0152***
	(0.088)	(0.138)	(0.064)	
Other puerperal infections	0.0378	0.0585	0.0309	0.0276***
	(0.191)	(0.235)	(0.173)	
Perineal laceration	0.0052	0.0001	0.0069	−0.0068***
	(0.072)	(0.010)	(0.083)	
Retained placenta and membranes	0.0178	0.0033	0.0226	−0.0194***
	(0.132)	(0.057)	(0.149)	
Observations	39477	9842	29635	39477

Note: Difference in means test * p<0.1, ** p<0.05, *** p<0.01. Analytical sample 1, 31754 deliveries on Sundays in 14 maternity units with surgical capabilities. Analytical sample 2, 39754 child deliveries on Sundays in 50 maternity units. Standard deviation in parentheses.

and retained placenta and membranes -1.9%, representing that there are more of these cases in vaginal deliveries than in C-sections, all of them statistically significant at conventional levels.

I argue that the number of obstetricians on Sundays are scheduled in advance considering the expected number of deliveries and C-sections on a given Sunday, but the actual realisation of the number of women that show up to the maternity unit can be lower or higher than expected, generating a random variation in the ratio obstetricians/child deliveries.

Table 4.2 presents an summary statistics on the relationship between C-section rates and obstetricians per patient. On average the proportion of C-sections increases with the number of obstetricians per day and decreases with the number of child deliveries per day.

Table (4.2) C-section rate on Sundays by number of obstetricians on duty per day and volume of child deliveries: means and standard deviation

	Number of child deliveries per day/maternity unit					
	<6	6-10	11-15	16-20	>20	Total
Number of obstetricians per day 1 (<3 obstetricians)	0.305 (0.461)	0.249 (0.432)	0.264 (0.441)	0.269 (0.445)	0.364 (0.492)	0.276 (0.447)
Number of obstetricians per day 2 (3-4 obstetricians)	0.355 (0.479)	0.312 (0.463)	0.284 (0.451)	0.251 (0.434)	0.228 (0.421)	0.303 (0.460)
Number of obstetricians per day 3 (5-6 obstetricians)	0.425 (0.497)	0.352 (0.478)	0.322 (0.467)	0.271 (0.444)	0.262 (0.440)	0.317 (0.465)
Number of obstetricians per day 4 (7-8 obstetricians)		0.385 (0.487)	0.345 (0.476)	0.309 (0.463)	0.305 (0.461)	0.334 (0.472)
Number of obstetricians per day 5 (9-10 obstetricians)		0.579 (0.507)	0.420 (0.494)	0.359 (0.480)	0.331 (0.471)	0.367 (0.482)
Number of obstetricians per day 6 (>10 obstetricians)			0.435 (0.499)	0.322 (0.468)	0.319 (0.466)	0.322 (0.467)
Total	0.327 (0.469)	0.311 (0.463)	0.313 (0.464)	0.283 (0.451)	0.311 (0.463)	0.310 (0.462)

Note: The table contains the means of C-sections and the standard deviation (in parentheses) for each combination of number of child deliveries and number of obstetricians. The sample consists of 31754 child deliveries on Sundays in 14 maternity units with surgical capabilities from 2011 to 2015

Table 4.3 presents the mean in the number of obstetricians, deliveries and C-sections per maternity unit. With few exceptions, e.g. provider 1 has one of the highest rates of obstetricians/deliveries but the lowest rate of C-sections, the relationship between the ratio obstetricians/deliveries and the rate of C-sections is positive, so it seems that providers with more obstetricians per deliveries perform more C-sections. Note however I am interested in the relationship within providers, and provider fixed effects are included in the model.

In the theoretical approach I argue for the possibility that some co-morbidities may be affected by the decision to perform a C-section (upcoded), and as I control for co-morbidities in the C-section regression, I could end up including non-independent variables in the regression. For dealing with this potential problem only co-morbidities of the antenatal care period are included as control variables.

The descriptive statistics of all control variables used in the analysis for each analytical sample are presented in the Appendix (Table A4.1 and A4.2).

Table (4.3) Descriptive statistics by provider

	obstetricians		Deliveries		Ratio obstetricians/deliveries		C-section rate	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Provider 1	1.81	0.82	3.45	2.01	0.63	0.29	0.15	0.23
Provider 2	3.84	1.33	7.88	2.78	0.52	0.18	0.23	0.16
Provider 3	1.99	0.98	3.04	1.60	0.72	0.29	0.38	0.34
Provider 4	2.88	1.18	6.47	3.05	0.50	0.22	0.32	0.24
Provider 5	4.23	1.74	14.57	4.48	0.30	0.13	0.23	0.14
Provider 6	1.64	0.94	2.53	1.36	0.71	0.32	0.40	0.38
Provider 7	3.24	1.34	4.86	2.38	0.73	0.21	0.41	0.28
Provider 8	1.81	1.29	6.73	2.65	0.30	0.23	0.27	0.18
Provider 9	3.69	1.31	8.23	3.16	0.49	0.18	0.34	0.19
Provider 10	4.88	1.65	9.38	3.84	0.57	0.19	0.31	0.18
Provider 11	4.02	1.55	10.54	4.26	0.43	0.18	0.31	0.19
Provider 12	4.51	1.84	11.01	4.24	0.45	0.19	0.37	0.19
Provider 13	4.87	2.35	13.01	4.98	0.41	0.21	0.39	0.18
Provider 14	10.86	4.36	22.03	11.76	0.56	0.18	0.34	0.13

Note: The column 'obstetricians' contains the means of the number of obstetricians and standard deviations for each of the 14 providers with surgical capabilities. The column 'deliveries' the means and standard deviations for the number of deliveries, the column 'ratio obstetricians/deliveries' has the means and standard deviations of the ratio of number of obstetricians and deliveries presented in the previous columns. The column 'C-section rate' the means and standard deviation of C-section rates in each provider.

4.6 Results

4.6.1 Women's C-section risk orthogonality with the ratio obstetricians/child deliveries

Using information on all deliveries of sample 1, Table 4.4 shows the logistic regression results for equation 4.2, where the predicted $\hat{h}_i$ represents the overall C-section risk using only co-morbidities of the antenatal care period. This also represent women's observed health status as a summary of antenatal co-morbidities.

Figure 4.4 presents the relationship between estimated C-section risk which summarises women's health status and C-section rates with the ratio of obstetricians/child deliveries for provider 1. Each observation represents a Sunday for provider 1. It is observed that on some Sundays there are more obstetricians and more C-sections are performed, but the mean predicted C-section risk is constant. This pattern is observed in the other 13 providers (see Figures A4.1 and A4.2 in the Appendix) which suggest that predicted C-section risk is not related to the number of obstetricians but the rate of C-sections is.

Table 4.5 tabulates the distribution of this estimated C-section risk in nine groups. Predicted C-section risk has a left skewed distribution. The C-section rate increases as this overall health status indicator rises.

Table 4.6 presents results from an OLS regression of C-section risk $\hat{h}_i$ against the obstetricians/deliveries ratio, controlling for provider effects. Controlled for maternity unit dummies, the ratio of obstetricians/child deliveries is not significant, signalling that women with different co-morbidities choose different kind of providers, but there is no relationship between the ratio obstetricians/child deliveries and co-morbidities within maternity units on Sundays.

I also regress, within each of the 14 providers, each of the 19 individual co-morbidity ICD codes

Table (4.4) Determinants of C-section risk on Sundays (h_i) as determined by antenatal characteristics: Logistic regression.

	(1) CS	
	β/SE	dydx
Age 1 (< 21 years)	-0.098^{***}	-0.019^{***}
	(0.037)	
Age 2 (21 - 25 years)	0.014	0.003
	(0.037)	
Age 3 (26 - 30 years)	Ref.	Ref.
Age 4 (31 - 35 years)	0.025	0.005
	(0.043)	
Age 5 (> 35 years)	0.035	0.007
	(0.048)	
Delivery before	-0.306^{***}	-0.060^{***}
	(0.054)	
Length of stay (in days) before delivery	0.069^{***}	0.014^{***}
	(0.008)	
Gestational hypertension	0.146^{**}	0.029^{**}
	(0.065)	
Pre-eclampsia	0.222^{***}	0.044^{***}
	(0.055)	
Haemorrhage in early pregnancy	0.056	0.011
	(0.095)	
Diabetes mellitus in pregnancy	0.048	0.009
	(0.101)	
Maternal care for other conditions	-0.015	-0.003
	(0.072)	
Multiple gestation	1.845^{***}	0.363^{***}
	(0.195)	
Known or suspected malpresentation of foetus	0.645^{***}	0.127^{***}
	(0.068)	
Known or suspected disproportion	0.610^{***}	0.120^{***}
	(0.061)	
Known or suspected abnormality of pelvic organs	1.585^{***}	0.312^{***}
	(0.042)	
Known or suspected foetal abnormality and damage	0.341^{*}	0.067^{*}
	(0.184)	
Known or suspected foetal problems	0.095^{*}	0.019^{*}
	(0.057)	
Polyhidrammios	0.197	0.039
	(0.128)	
Disorders of amniotic fluid and membranes	-0.152	-0.030
	(0.096)	
Premature rupture of membranes	0.242^{**}	0.048^{**}
	(0.109)	
Placental disorders	0.111	0.022
	(0.081)	
Placenta praevia	0.591^{***}	0.116^{***}
	(0.126)	
False labour	0.181^{***}	0.036^{***}
	(0.048)	
Prolonged pregnancy	0.159	0.031
	(0.133)	
Infectious and parasitic diseases classifiable elsewhere	0.208^{*}	0.041^{*}
	(0.126)	
Constant	-1.086^{***}	
	(0.029)	
Observations	31754	
Pseudo R^2	0.060	
LR chi2	1993.387	
Prob > chi2	0.000	
Log Likelihood	-18473.512	
Degree of Freedom	25.000	
AIC	36999.025	
BIC	37216.535	

Note: * p<0.1, ** p<0.05, *** p<0.01. Dependent variable: Dummy for women having a C-section on a Sunday. Robust standard errors in parentheses. Coefficients and standard errors in parenthesis in the first column, marginal effects in the second column.

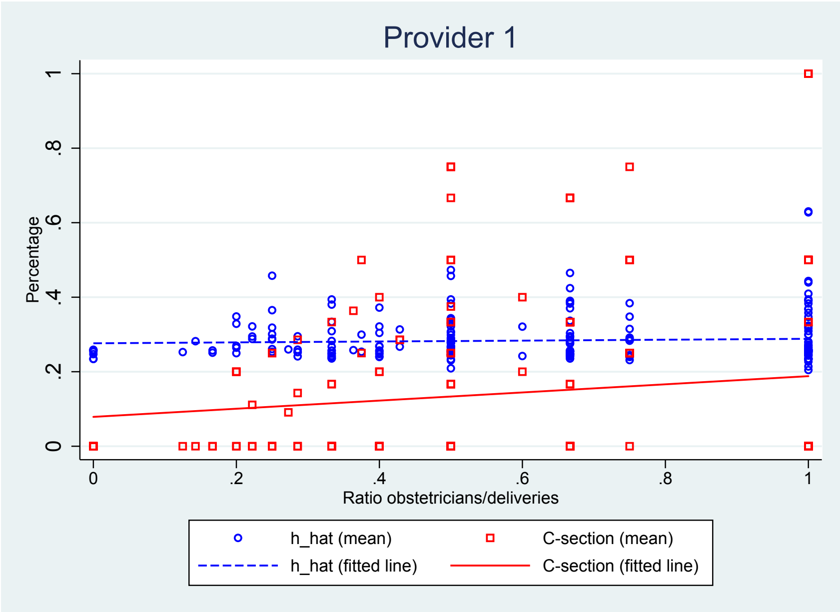

Figure (4.4) Ratio obstetricians/child deliveries and C-section rates and mean women's C-section risk $\hat{h}_i$ predicted with a logistic regression using antenatal care co-morbidities for provider 1

Table (4.5) Estimated C-section risk $\hat{h}_i$ by groups

Group	$\hat{h}_i$ values	Deliveries	C-sections (%)	Obs (%)
1	$\hat{h}_i$ < 0.20	468	18.2	1.5
2	0.20≤ $\hat{h}_i$ <0.30	23,717	24.8	74.7
3	0.30≤ $\hat{h}_i$ <0.40	3,293	38.3	10.4
4	0.40≤ $\hat{h}_i$ <0.50	797	46.9	2.5
5	0.50≤ $\hat{h}_i$ <0.60	690	55.8	2.2
6	0.60≤ $\hat{h}_i$ <0.70	2,069	66.3	6.5
7	0.70≤ $\hat{h}_i$ <0.80	556	66.4	1.8
8	0.80 ≤ $\hat{h}_i$ <0.90	133	72.9	0.4
9	$\hat{h}_i$ ≥ 0.90	31	87.1	0.1
	Observations	31,754		

Note: The C-section risk $\hat{h}_i$ is estimated as the probability of C-sections using the results in Table 4.4.

Table (4.6) OLS regression for independence test dependant variable estimated women's C-section risk $\hat{h}_i$ against ratio of obstetricians and volume of child deliveries

	(1) OLS		(2) OLS	
	β	SE	β	SE
Capacity variable				
Ratio obstetricians/child deliveries	0.001	(0.004)	−0.001	(0.005)
Provider dummies				
Provider 1	Ref.		Ref.	
Provider 2	0.009**	(0.004)	−0.028*	(0.016)
Provider 3	0.047***	(0.006)	−0.014	(0.018)
Provider 4	−0.004	(0.004)	−0.013	(0.017)
Provider 5	0.023***	(0.004)	−0.013	(0.015)
Provider 6	0.028***	(0.006)	0.086***	(0.026)
Provider 7	0.041***	(0.005)	−0.006	(0.017)
Provider 8	0.023***	(0.005)	−0.016	(0.014)
Provider 9	0.075***	(0.005)	0.066**	(0.030)
Provider 10	0.013***	(0.004)	0.096***	(0.037)
Provider 11	0.015***	(0.004)	−0.034**	(0.014)
Provider 12	0.046***	(0.004)	0.046***	(0.014)
Provider 13	0.031***	(0.004)	0.011	(0.016)
Provider 14	0.020***	(0.004)	−0.015	(0.014)
Constant	0.284***	(0.004)	0.302***	(0.012)
Staff dummies	no		yes	
Observations	31754		31592	

Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parentheses.

with the ratio of obstetricians/deliveries (a bivariate linear regression), and find no systematic relationships (see Table A4.3 in the Appendix for details).

4.6.2 Effect of capacity on C-sections

In this subsection I estimate the effect of the ratio number of obstetricians/volume of child deliveries on women's exposure to C-sections.

Column 1 in Table 4.7 shows the regression results for equation (4.3), and in column 2 the estimation of equation (4.4) with full quadratic iterations, both with maternity unit dummy variables. Columns 3 and 4 presents the same specification including staff dummies to capture obstetricians' fixed effects [3]. The maternity unit dummies are not then redundant because an obstetrician can be observed in more than one unit.

Columns 1 and 2 of Table 4.8 represents the marginal effects of the fully quadratic form, which corresponds to columns 2 and 4 of Table 4.7 respectively. The second column that includes the obstetricians' fixed effect is my preferred specification because it controls for unobserved characteristics of the obstetrician. The quadratic interaction captures the assumption developed in the theoretical part, that the obstetricians/deliveries ratio will only affect the probability of a C-section for women of intermediate risk. High risk C-section women will always get a C-section and very low C-section risk women will not get a C-section.

The first coefficient of the second column in Table 4.8 estimates a marginal effect of 0.085 for the ratio obstetricians/deliveries, which is statistically significant. One standard deviation increase in the ratio obstetricians/deliveries (0.20) increases the rate of C-section by about 1.7%.

[3] In fact I include all staff fixed effects, which include midwives, this does not affect the estimation because I am interested in the effect of the the ratio obstetricians/child deliveries on C-sections, and midwives do not perform C-sections.

Table (4.7) OLS regression results: Dependant variable C-section on Sunday

	(1) OLS β/(SE)	(2) OLS β/(SE)	(3) OLS β/(SE)	(4) OLS β/(SE)
Ratio obstetricians/child deliveries	0.146*** (0.015)	−0.833*** (0.197)	0.094*** (0.016)	−0.859*** (0.194)
Ratio obstetricians/child deliveries squared		0.821*** (0.253)		0.864*** (0.248)
Ratio obstetricians/child deliveries × $\hat{h}_i$		5.149*** (0.915)		5.064*** (0.895)
Ratio obstetricians/child deliveries squared × $\hat{h}_i$		−4.405*** (1.256)		−4.672*** (1.229)
Ratio obstetricians/child deliveries × $\hat{h}_i$ squared		−5.681*** (0.920)		−5.831*** (0.901)
Ratio obstetricians/child deliveries squared × $\hat{h}_i$ squared		5.022*** (1.304)		5.514*** (1.279)
Patient's characteristics	yes	yes	yes	yes
Maternity unit dummies	yes	yes	yes	yes
Staff dummies	no	no	yes	yes
Observations	31754	31754	31592	31592

Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parentheses. Column (1) is the model with patient's characteristics and maternity unit dummies and with no staff dummies. Column (2) includes the same as column (1) plus full quadratic interaction of the ratio obstetricians/child deliveries with women's C-section risk $\hat{h}_i$. Column (3) and (4) adds to the two previous models staff dummies, respectively. Patient's characteristics includes all covariates reported in Table 4.4. Maternity dummies include 13 dummies for 14 providers equipped for providing child delivery by vaginal delivery and C-sections. I include 641 staff dummies; among them there are 454 obstetricians responsible for 87% of child deliveries, the remaining dummies correspond to general physicians and midwives responsible mainly for vaginal deliveries.

Table (4.8) Marginal effect ratio obstetricians/volume of child deliveries on C-sections by women's health status

	(1) OLS Marg. eff.	 (SE)	(2) OLS Marg. eff.	 (SE)
Average marginal effect				
Ratio obstetricians/child deliveries	0.141***	(0.016)	0.085***	(0.018)
Marginal effect at health status values				
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.2	0.093***	(0.022)	0.052**	(0.024)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.3	0.158***	(0.017)	0.099***	(0.019)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.4	0.197***	(0.025)	0.127***	(0.026)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.5	0.211***	(0.032)	0.134***	(0.033)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.6	0.199***	(0.038)	0.121***	(0.038)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.7	0.161***	(0.048)	0.088*	(0.048)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.8	0.098	(0.067)	0.035	(0.065)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.9	0.009	(0.095)	−0.038	(0.093)
Patient's characteristics	yes		yes	
Maternity unit dummies	yes		yes	
Staff dummies	no		yes	
Observations	31754		31592	

Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parentheses. Column (1) and (2) present the marginal effects of models in columns (2) and (4) presented in Table 4.7, respectively

The following rows estimate the marginal effect on specific women's health status, where I observe that for women with health status of $\hat{h} = 0.2$. A one standard deviation increases in the ratio obstetricians/child deliveries increases C-sections by 1%. This increases up to 2.7% for women with health status of $\hat{h} = 0.5$ and then decreases up to 1.8% for women with $\hat{h} = 0.7$. At the tail it is not longer significant above this value.

I also use higher degree polynomial interactions (up to order 4) (see Table A4.4 in the Appendix) and the effect remains with little change.

For further sensitivity analysis, I use separate categorical variables for number of obstetricians and volume of child deliveries per day. As predicted in the theoretical part, I found that the probability of a woman getting a C-section is higher if there are a higher number of obstetricians on duty. This is because of an increase in the surgical capabilities of the maternity unit, and this probability decreases when the number of women that show up to the maternity unit increases (see table A4.5 in the Appendix for details). This last effect is due to the limited surgical capabilities. Obstetricians are sorting only women with higher health risk status to C-sections (see Table A4.6 in the Appendix).

4.6.3 Effect of the ratio obstetricians/child deliveries on upcoding

Table 4.9 presents the marginal effects for the equations (4.5) and (4.6) for four candidate codes.

I focus on columns 2, 4, 6 and 8 which reports marginal effects including obstetrician fixed effects. The first coefficient of column 2 reports the overall marginal effects for prolonged pregnancy 0.014, which is statistically significant, then one standard deviation on the ratio obstetricians/child deliveries increases the probability of using this code in 0.3%.

The heterogeneity of results in the following rows show that for women with health status $\hat{h} = 0.2$, there is no statistically significant effect, so there is no evidence of upcoding for very healthy women using prolonged pregnancy code.

For higher value of $\hat{h} = 0.3$ the probability of upcoding is 0.3% rising up to 0.5% when $\hat{h} = 0.5$ then decreasing to 0.4% for $\hat{h} = 0.7$ after which there is no statistically significant effect.

The overall marginal effect of upcoding using pelvic abnormality given one standard deviation increasing in the ratio obstetricians/child deliveries is 0.4%, with the first coefficient of column 4, mainly from women with health status $\hat{h} = 0.3$ and in a lesser degree from women with $\hat{h} = 0.4$.

There is strong evidence of using foetal distress to justify C-sections, where the first coefficient of column 6 shows that one standard deviation on the ratio obstetricians/child deliveries increases foetal distress by 0.58%, and surprisingly this is higher at lower levels of women's health status. The second row of column 6 show that at values of $\hat{h} = 0.2$ the chances of using this code is 0.62%, which reduces up to 0.52 when $\hat{h} = 0.5$ and after that the effects are no longer statistically different from zero.

Regarding the inclusion of umbilical cord complications, I find evidence of upcoding for women with health status values of $\hat{h} = 0.3$ with 0.24% of increase in the use of this code, upon a standard deviation increase in the ratio obstetricians/child deliveries, up to the value $\hat{h} = 0.5$ with 0.44% in this increase.

So from the four variables, I find strong evidence of the use of prolonged pregnancy and foetal distress. Interestingly the evidence of the use of foetal distress is for very healthy women, so it seems that obstetricians prefer to use babies' co-morbidities to justify performing C-sections on healthy women.

Table (4.9) Marginal effect of ratio obstetricians/volume of child deliveries on co-morbidity coding

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Prolonged pregnancy		Pelvic abnormality		Foetal distress		Umbilical cord complications	
	Marg. eff.	Marg. eff.	Marg. eff.	Marg. eff.	Marg. eff.	Marg. eff.	Marg. eff.	Marg. eff.
Average marginal effect								
Ratio obstetricians/child deliveries	0.016***	0.014***	0.055***	0.022**	0.028***	0.029***	0.011**	0.007
	(0.004)	(0.005)	(0.010)	(0.011)	(0.007)	(0.008)	(0.004)	(0.005)
Marginal effect at health status values								
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.2	0.006	0.006	0.034**	0.012	0.028***	0.031***	−0.004	−0.005
	(0.006)	(0.006)	(0.015)	(0.016)	(0.010)	(0.011)	(0.008)	(0.009)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.3	0.018***	0.016***	0.059***	0.025**	0.029***	0.029***	0.017***	0.012*
	(0.004)	(0.005)	(0.011)	(0.012)	(0.008)	(0.009)	(0.006)	(0.006)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.4	0.026***	0.023***	0.077***	0.034*	0.028**	0.028**	0.029***	0.021**
	(0.006)	(0.007)	(0.019)	(0.020)	(0.011)	(0.012)	(0.010)	(0.011)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.5	0.029***	0.026***	0.088***	0.039	0.028**	0.026*	0.032***	0.022*
	(0.007)	(0.008)	(0.026)	(0.027)	(0.014)	(0.014)	(0.012)	(0.012)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.6	0.029***	0.025***	0.092***	0.039	0.028*	0.024	0.025**	0.015
	(0.008)	(0.009)	(0.034)	(0.034)	(0.016)	(0.016)	(0.012)	(0.013)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.7	0.024**	0.021**	0.088*	0.035	0.027	0.022	0.010	0.000
	(0.009)	(0.010)	(0.046)	(0.046)	(0.021)	(0.021)	(0.015)	(0.016)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.8	0.015	0.012	0.078	0.026	0.026	0.019	−0.015	−0.023
	(0.013)	(0.014)	(0.065)	(0.065)	(0.031)	(0.032)	(0.026)	(0.027)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.9	0.003	0.000	0.061	0.013	0.024	0.016	−0.049	−0.054
	(0.021)	(0.021)	(0.094)	(0.094)	(0.047)	(0.048)	(0.044)	(0.045)
Patient's characteristics	yes	yes	yes	yes	yes	yes	yes	yes
Maternity unit dummies	yes	yes	yes	yes	yes	yes	yes	yes
Staff dummies	no	yes	no	yes	no	yes	no	yes
Observations	31754	31592	31754	31592	31754	31592	31754	31592

Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parenthesis. The coefficients represent the effect of the ratio obstetrician/volume of child deliveries on co-morbidity. Patient's characteristics included. Maternity dummies include 13 dummies for 14 providers equipped for providing child delivery by vaginal delivery and C-sections. I include 814 staff dummies among them and where there are 481 obstetricians responsible for 87% of child deliveries, the remaining dummies correspond to general physicians and midwives responsible mainly for vaginal deliveries.

Table 4.10 presents the placebo test using diabetes to test if changes in the ratio obstetricians/child deliveries improves the general diagnosis of co-morbidities, in which case the rise in the previous codes could have been accounted as better diagnosis rather than upcoding. From the preferred specification with staff fixed effects in column (2) it is observed that there is no effect of the ratio obstetrician/child deliveries on diabetes. These suggest that obstetricians are not improving their diagnoses when capacity (P_{kt}) increases.

Table (4.10) Marginal effect of placebo test for upcoding diabetes by women's C-section risk

	(1)	(2)
	Diabetes	
	dydx/(SE)	dydx/(SE)
Average marginal effect		
Ratio obstetricians/child deliveries	0.002	0.0002
	(0.002)	(0.002)
Marginal effect at health status values		
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.2	0.001	0.000
	(0.002)	(0.002)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.3	0.001	−0.000
	(0.002)	(0.002)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.4	0.002	−0.000
	(0.003)	(0.003)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.5	0.003	0.001
	(0.004)	(0.004)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.6	0.004	0.002
	(0.005)	(0.005)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.7	0.005	0.003
	(0.006)	(0.006)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.8	0.007	0.005
	(0.007)	(0.008)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.9	0.009	0.007
	(0.010)	(0.010)
Patient's characteristics	yes	yes
Maternity unit dummies	yes	yes
Staff dummies	no	yes
Observations	31754	31592

Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parenthesis. Patient's characteristics included. The coefficients are the effect of the ratio obstetrician/volume of child deliveries on diabetes coding. Maternity dummies include 13 dummies for 14 providers equipped for providing child delivery by vaginal delivery and C-sections. I include 814 staff dummies among them and there are 481 obstetricians responsible for 87% of child deliveries, the remaining dummies correspond to general physicians and midwives responsible mainly for vaginal deliveries.

4.6.4 Effect of the ratio obstetricians/child deliveries on health outcomes

The overall effect on health outcomes of greater capacity is in theory ambiguous: higher P_{kt} can improve outcomes for each procedure on a given woman but changes the mix of C-sections and vaginal deliveries.

Table 4.11 presents the results of the overall effect of the ratio obstetricians/child deliveries on six health outcomes using the specification of equations (4.7) and (4.8).

Table (4.11) Marginal effect on women's health outcomes of the ratio obstetricians/volume of child deliveries by women's health status

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Maternal death		Haemorrhage		Sepsis		Infection		Laceration		Retained placenta	
	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)
Average marginal effect												
Ratio obstetricians/child deliveries	0.0005	0.001	−0.026***	−0.027***	−0.012***	−0.003	0.029***	0.017**	0.003	0.005	−0.001	−0.002
	(0.001)	(0.001)	(0.005)	(0.006)	(0.004)	(0.004)	(0.007)	(0.008)	(0.003)	(0.004)	(0.006)	(0.007)
Marginal effect by health status values												
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.2	0.0003	0.001	−0.027***	−0.030***	−0.012***	−0.002	0.018**	0.005	0.006*	0.009**	0.002	0.000
	(0.001)	(0.001)	(0.006)	(0.007)	(0.004)	(0.005)	(0.009)	(0.010)	(0.003)	(0.004)	(0.007)	(0.008)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.3	0.001	0.001	−0.023***	−0.025***	−0.010**	−0.002	0.037***	0.024***	0.002	0.005	0.002	0.000
	(0.001)	(0.001)	(0.005)	(0.006)	(0.004)	(0.004)	(0.007)	(0.009)	(0.003)	(0.004)	(0.006)	(0.007)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.4	0.001	0.001	−0.022***	−0.022***	−0.009*	−0.003	0.045***	0.032***	−0.001	0.002	−0.003	−0.005
	(0.001)	(0.001)	(0.006)	(0.007)	(0.005)	(0.006)	(0.011)	(0.012)	(0.003)	(0.004)	(0.007)	(0.007)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.5	0.001	0.002	−0.021***	−0.021**	−0.010	−0.004	0.043***	0.031**	−0.002	0.001	−0.014*	−0.015*
	(0.001)	(0.001)	(0.008)	(0.009)	(0.007)	(0.007)	(0.014)	(0.015)	(0.004)	(0.004)	(0.008)	(0.009)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.6	0.0005	0.001	−0.023**	−0.021**	−0.012	−0.007	0.030	0.019	−0.002	0.000	−0.030***	−0.030***
	(0.001)	(0.001)	(0.009)	(0.010)	(0.008)	(0.008)	(0.017)	(0.018)	(0.005)	(0.005)	(0.009)	(0.010)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.7	0.0002	0.001	−0.026**	−0.023*	−0.016	−0.012	0.007	−0.002	−0.001	0.001	−0.051***	−0.051***
	(0.000)	(0.001)	(0.012)	(0.012)	(0.010)	(0.010)	(0.022)	(0.023)	(0.007)	(0.007)	(0.011)	(0.012)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.8	−0.0003	0.001	−0.031*	−0.027	−0.020	−0.017	−0.026	−0.034	0.002	0.004	−0.078***	−0.076***
	(0.001)	(0.001)	(0.017)	(0.018)	(0.014)	(0.014)	(0.031)	(0.032)	(0.009)	(0.009)	(0.014)	(0.015)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.9	−0.001	0.000	−0.037	−0.033	−0.027	−0.023	−0.070	−0.076*	0.006	0.007	−0.110***	−0.107***
	(0.002)	(0.002)	(0.025)	(0.025)	(0.020)	(0.020)	(0.045)	(0.046)	(0.012)	(0.012)	(0.020)	(0.021)
Patient's characteristics	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Maternity unit dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Staff dummies	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes
Observations	39477	39265	39477	39265	39477	39265	39477	39265	39477	39265	39477	39265

Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parenthesis. The coefficients are the effect of the ratio obstetrician/volume of child deliveries on health outcomes. Maternity dummies include 49 dummies for 50 providers equipped for providing child delivery. I include 814 staff dummies among them there are 481 obstetricians responsible for 87% of child deliveries, the remaining dummies correspond to general physicians and midwives responsible mainly for vaginal deliveries.

The ratio obstetricians/child deliveries does not affect maternal death, column (2), or sepsis, column (6). It reduces haemorrhage, column (4), and retained placenta, column (12), but increases infections, column (8) and perineal laceration, column (10).

Overall, one standard deviation increase in the ratio obstetricians/child deliveries (0.25) reduces haemorrhages by 0.67%. This effect is mainly for healthy women. It seems that more obstetricians perform more C-sections in healthy women but also control or prevent haemorrhages, due to the availability or more skilled staff.

The ratio of obstetricians/child deliveries reduces retained placenta for high risk health status women. This is shown by the fifth coefficient in column 12 onwards. More specifically from health status $\hat{h} = 0.5$ a one standard deviation increase in the ratio of obstetricians/child deliveries reduces the probability of retained placenta by 0.38%, this progressively increases up to 2.68% for women with health status $\hat{h} = 0.9$.

In contrast, I find evidence of capacity increasing cases of perineal laceration but only for healthy women for $\hat{h} = 0.2$, column (10). One standard deviation increase in the ratio of obstetricians/child deliveries increases the probability of perineal laceration in 0.23% for this sub population. As this health outcome is related mainly to vaginal deliveries, this is likely due to the use of a high intervention procedure: the episiotomy. I cannot verify this, because I do not have reliable records of this procedure in the database, but this is consistent with several studies reporting that the rates of episiotomy were higher among women planning birth in an obstetric unit (National Institute for Health and Care Excellence - NICE, 2017).

I also find evidence in the effect of capacity on increasing puerperal infections, in column (8). One standard deviation increase in the ratio of obstetricians/child deliveries increases the overall probability of suffering puerperal infection by 0.43%, and from the heterogeneity I find that this effect is mainly for women with relatively low co-morbidities, from $\hat{h} = 0.3$ (0.60%) to $\hat{h} = 0.5$ (0.78%).

Arguably the effect of increases in more interventionist procedures as capacity increases, including C-sections, prevails over the direct quality channel in this case. This finding is remarkable, because it is likely that infections are controlled by a greater number of staff, then the harm caused by the interventionist procedures is such that even with more obstetricians to control them, the bad effect still prevails.

Tables 4.12 and 4.13 present the marginal effects of the ratio obstetricians/child deliveries on six health outcomes on obstetrician-led providers and midwife-led providers, respectively, using the specification of equation (4.9).

Table (4.12) Marginal effect on women's health outcomes of the ratio of obstetricians/child deliveries by women's health status on obstetrician-led providers

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Maternal death		Haemorrhage		Sepsis		Infection		Laceration		Retained placenta	
	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)
Average marginal effect												
Ratio obstetricians/child deliveries	0.001	0.001	−0.029***	−0.029***	−0.007**	−0.0004	0.024***	0.010	0.003	0.004	−0.007	−0.007
	(0.001)	(0.001)	(0.004)	(0.005)	(0.003)	(0.004)	(0.006)	(0.007)	(0.003)	(0.003)	(0.005)	(0.005)
Marginal effect by health status values												
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.2	0.0003	0.0005	−0.029***	−0.029***	−0.005	0.003	0.014	−0.0004	0.007**	0.009**	−0.006	−0.006
	(0.001)	(0.001)	(0.006)	(0.006)	(0.005)	(0.005)	(0.010)	(0.010)	(0.004)	(0.004)	(0.006)	(0.007)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.3	0.001	0.001	−0.029***	−0.028***	−0.007*	−0.000	0.030***	0.017**	0.002	0.003	−0.002	−0.003
	(0.001)	(0.001)	(0.005)	(0.005)	(0.004)	(0.004)	(0.007)	(0.008)	(0.003)	(0.003)	(0.005)	(0.006)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.4	0.001	0.001	−0.029***	−0.028***	−0.009*	−0.004	0.037***	0.025**	−0.002	−0.000	−0.004	−0.005
	(0.001)	(0.001)	(0.006)	(0.007)	(0.005)	(0.005)	(0.011)	(0.012)	(0.003)	(0.003)	(0.007)	(0.007)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.5	0.001	0.002	−0.030***	−0.028***	−0.010*	−0.006	0.036***	0.024*	−0.004	−0.002	−0.012	−0.012
	(0.001)	(0.001)	(0.007)	(0.008)	(0.006)	(0.006)	(0.014)	(0.014)	(0.003)	(0.004)	(0.008)	(0.008)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.6	0.001	0.001	−0.032***	−0.030***	−0.012*	−0.008	0.026*	0.014	−0.004	−0.002	−0.025***	−0.025***
	(0.001)	(0.001)	(0.008)	(0.008)	(0.007)	(0.007)	(0.015)	(0.016)	(0.004)	(0.004)	(0.008)	(0.008)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.7	0.0001	0.001	−0.035***	−0.032***	−0.013	−0.010	0.006	−0.004	−0.002	−0.001	−0.043***	−0.042***
	(0.000)	(0.001)	(0.010)	(0.011)	(0.009)	(0.009)	(0.019)	(0.020)	(0.005)	(0.005)	(0.008)	(0.009)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.8	−0.0004	0.0002	−0.038**	−0.035**	−0.014	−0.011	−0.022	−0.032	0.002	0.002	−0.067***	−0.064***
	(0.001)	(0.001)	(0.016)	(0.017)	(0.014)	(0.014)	(0.030)	(0.032)	(0.008)	(0.008)	(0.012)	(0.012)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.9	−0.001	−0.001	−0.042	−0.038	−0.015	−0.012	−0.059	−0.069	0.007	0.007	−0.096***	−0.091***
	(0.002)	(0.002)	(0.026)	(0.027)	(0.022)	(0.021)	(0.048)	(0.050)	(0.011)	(0.011)	(0.018)	(0.019)
Patient's characteristics	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Maternity unit dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Staff dummies	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes
Observations	39477	39265	39477	39265	39477	39265	39477	39265	39477	39265	39477	39265

Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parenthesis. The estimated model is (4.9). The coefficients are the effect of the ratio obstetrician/volume of child deliveries on health outcomes. The regression is fitted with a dummy variable, 1 obstetrician-led providers and 0 midwife-led providers, which is interacted with the ratio of obstetricians/child deliveries and the predicted C-section risk. Maternity dummies include 49 dummies for 50 providers equipped for providing child delivery. I include 814 staff dummies among them there are 481 obstetricians responsible for 87% of child deliveries, the remaining dummies correspond to general physicians and midwives responsible mainly for vaginal deliveries.

Table (4.13) Marginal effect on women's health outcomes of the ratio of obstetricians/child deliveries by women's health status on midwife-led providers

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Maternal death		Haemorrhage		Sepsis		Infection		Laceration		Retained placenta	
	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)	dydx/(SE)
Average marginal effect												
Ratio obstetricians/child deliveries	−0.000	0.001	−0.003	−0.017	−0.030***	−0.020**	0.048**	0.034	0.001	0.005	0.034*	0.028
	(0.001)	(0.002)	(0.013)	(0.013)	(0.009)	(0.010)	(0.019)	(0.024)	(0.007)	(0.008)	(0.018)	(0.023)
Marginal effect by health status values												
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.2	−0.00002	0.001	−0.039	−0.060*	−0.038***	−0.027**	0.026	0.010	−0.002	0.003	−0.003	−0.018
	(0.001)	(0.002)	(0.026)	(0.032)	(0.011)	(0.013)	(0.035)	(0.039)	(0.009)	(0.010)	(0.033)	(0.030)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.3	−0.00002	0.0005	0.024	0.016	−0.024***	−0.014	0.065**	0.052	0.002	0.007	0.062	0.064
	(0.001)	(0.002)	(0.024)	(0.020)	(0.009)	(0.010)	(0.028)	(0.032)	(0.006)	(0.008)	(0.039)	(0.045)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.4	−0.0001	0.0003	0.081	0.087	−0.018	−0.009	0.089	0.080	0.006	0.010	0.123	0.141
	(0.001)	(0.002)	(0.065)	(0.061)	(0.013)	(0.013)	(0.069)	(0.075)	(0.006)	(0.007)	(0.099)	(0.106)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.5	0.0001	0.0004	0.133	0.152	−0.020	−0.012	0.097	0.094	0.009	0.013	0.179	0.215
	(0.001)	(0.002)	(0.106)	(0.103)	(0.016)	(0.017)	(0.113)	(0.120)	(0.008)	(0.008)	(0.161)	(0.169)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.6	0.00005	0.0005	0.179	0.211	−0.030	−0.023	0.089	0.094	0.010	0.015	0.230	0.283
	(0.001)	(0.002)	(0.148)	(0.146)	(0.020)	(0.021)	(0.156)	(0.166)	(0.011)	(0.011)	(0.223)	(0.231)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.7	0.0001	0.001	0.219	0.265	−0.048*	−0.042	0.066	0.080	0.012	0.016	0.277	0.347
	(0.002)	(0.002)	(0.189)	(0.189)	(0.026)	(0.027)	(0.200)	(0.213)	(0.014)	(0.014)	(0.285)	(0.293)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.8	0.0001	0.001	0.254	0.314	−0.073**	−0.068*	0.026	0.052	0.012	0.017	0.320	0.406
	(0.002)	(0.002)	(0.232)	(0.233)	(0.037)	(0.039)	(0.246)	(0.261)	(0.019)	(0.020)	(0.348)	(0.356)
Ratio obstetricians/child deliveries × $\hat{h}_i$=0.9	0.0002	0.002	0.284	0.357	−0.107**	−0.102*	−0.029	0.010	0.012	0.017	0.357	0.461
	(0.002)	(0.003)	(0.275)	(0.278)	(0.053)	(0.055)	(0.295)	(0.313)	(0.026)	(0.027)	(0.410)	(0.419)
Patient's characteristics	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Maternity unit dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Staff dummies	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes
Observations	39477	39265	39477	39265	39477	39265	39477	39265	39477	39265	39477	39265

Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parenthesis. The estimated model is (4.9). The coefficients are the effect of the ratio obstetrician/volume of child deliveries on health outcomes. The regression is fitted with a dummy variable, 1 obstetrician-led providers and 0 midwife-led providers, which is interacted with the ratio of obstetricians/child deliveries and the predicted C-section risk. Maternity dummies include 49 dummies for 50 providers equipped for providing child delivery. I include 814 staff dummies among them there are 481 obstetricians responsible for 87% of child deliveries, the remaining dummies correspond to general physicians and midwives responsible mainly for vaginal deliveries.

Comparing columns (2), (4), (6) and (8) of both tables I find that the effects described previously comes from obstetricians working in obstetrician-led providers where C-sections can be performed, with the notable exception of sepsis in column (6). Table 4.13, that shows that more obstetricians per woman reduces sepsis, arguably more obstetrician on duty in maternity units with no operating theatres reduces this complication. A higher P_{kt} has obtain different health outcomes effect depending on the availability of operating theatre or not.

Figure 4.5 plots my main results, which are the effect of the ratio of obstetricians/child deliveries on C-sections; the upcoding of prolonged pregnancy to the mother and foetal distress to the baby to justify C-sections, and the effect on puerperal infections. I note that even though the point estimates vary, the confidence intervals overlap.

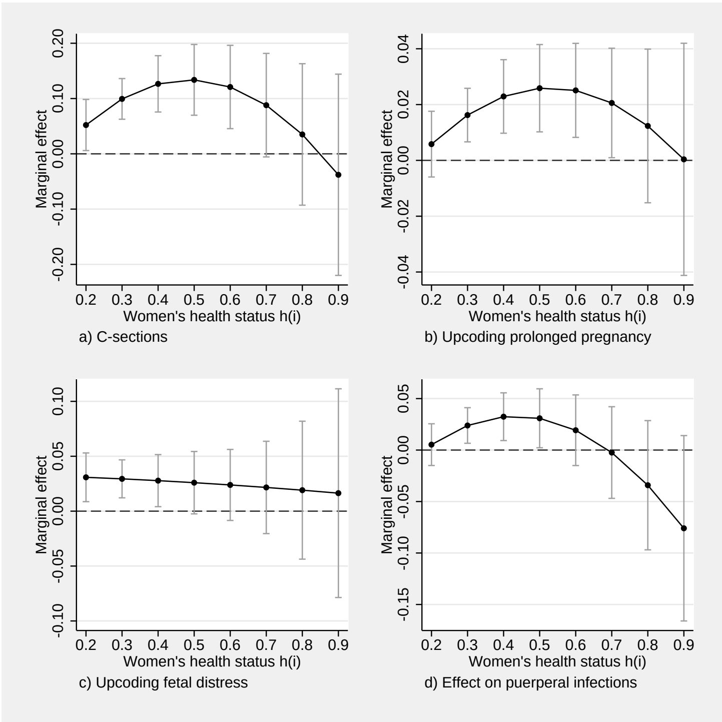

Figure (4.5) Marginal effects comparison: physicians upcode newborn co-morbidity for progressively healthier women

To sum up, an increase in the number of obstetricians, or a reduction in the number of child deliveries, increases the risk of C-section as obstetricians upcode co-morbidities for the mother, and for very healthy women, co-morbidities for the baby, to justify their decision.

The overall effect is a reduction on retained placenta for high risk women, an increase of the probability in perineal laceration for very healthy women, probably because of an episiotomy, and an increase in the rate of puerperal infection, likely due to C-sections.

4.7 Discussion and concluding remarks

This chapter shows that when the ratio obstetricians/deliveries increases the C-sections also increases. Obstetricians upcode co-morbidities for the mother and the baby to justify C-sections. An increase in capacity affects health outcomes with mixed results.

A simple back of the envelope analysis, considering all women that give birth on Sundays when the ratio obstetrician/child deliveries was above the average 0.44 (Table 4.1) and multiplied by the coefficient estimated in the main model 0.085 (Table 4.8), shows that in the five year period there were 208 C-sections attributed merely to changes in the ratio obstetricians/deliveries. This is equivalent to 4 unneeded C-sections every five Sundays. The scale of the problem is bigger if we assume that the same also occurs in any day of the week, from Monday to Saturday, and this is likely conservative considering that in days of the week obstetricians can also allocate women according to capacity.

The methodology used is the linear probability model estimated on Sundays deliveries (where there are only unscheduled C-sections) using providers fixed effects to control for women's tastes for providers quality, which is assumed to be constant within providers. I also include in the regression obstetricians fixed effect which control for unobserved obstetricians' characteristics, this allows to examine if the same obstetrician behaves differently when capacity varies.

One way to reduce fluctuations in the obstetrician/delivery ratio (and hence potentially reduce over-use of C-sections and upcoding) would be a more flexible staffing system using on call duty rotas(Spetz et al., 2001). In the context of this research, this means that the ratio of deliveries to obstetricians would be less variable if obstetricians are available on-call. In the maternity units included in the study, there is an on-call system established but only in the event where a woman requires the attention of a highly specialised Consultant outside the scope of the normal functioning of the maternity unit, such as a neurologist or cardiologist. Obstetricians and anaesthetists are regularly programmed onto the rota and are excluded from the on-call system (Ministerio de Salud del Peru, 1992).

The fact that C-section rates increase when obstetricians/delivery ratio increases does not in itself imply that obstetricians place too high a value on C-sections given their health complications. It is possible that increasing the C-sections rate when capacity increases is socially beneficial because net social benefits of C-sections for the additional women treated is positive. But the finding that greater capacity leads to upcoding suggests that obstetricians realise that they put too high a value to C-sections. In this chapter, the use of daily variation of the number of obstetricians and volume of deliveries and the inclusion in the regression of obstetricians fixed effects, suggest that, obstetricians change their behaviour in a daily basis in response to variations in capacity. Women with different co-morbidities might choose higher level providers because of their quality. But I control for this because I use provider fixed effects.

Thus the relationship between volume-health outcomes examined in this research are due to the time of staff invested per woman. Greater volume of women reduces the ratio of obstetricians/child deliveries which potentially reduces the time to perform any procedure. So volume of child deliveries is inversely related to health outcomes as well as the number of obstetricians directly related to health outcomes. On the other hand, more obstetricians will also make it possible to use medically intensive procedures, harmful or not, with mixed results. Then the final effect will depend on which effect prevails.

These mixed results are reflected in the results, where the ratio of obstetricians/child deliveries increases perineal laceration and puerperal infections, arguably due to the overuse of medically intensive procedures, and reduces retained placenta and haemorrhage, in these cases arguably due to the time available to perform better procedures.

Clapp et al. (2014) suggest redirecting patients to obstetricians with high volume of child deliveries, but my findings suggest that obstetricians would adjust their behaviour to respond to this variation. And as maternity units can adjust their number of obstetricians, upon a permanent increase in the demand that such policy implies, the trend in C-section rate is unlikely to be affected.

Some studies (Betrán et al., 2018) propose midwife-led maternity units to reduce C-section rates. Although this chapter seems to support this recommendation, Chapter 2 shows that women prefer to bypass this kind of provider then, in the context of Lima, it seems that it is not possible to avoid women arriving at obstetrician-led facilities.

I present evidence of upcoding and argue that obstetricians are aware of guidelines and tend to justify their decision by upcoding co-morbidities in clinical records. One of the policy implications of my results is that there should be improved monitoring of coding.

Although this chapter analyses the effect of capacity on health outcomes which include the indirect channel through C-sections, it does not estimate the effect of C-sections on outcomes because capacity also affects outcomes conditional on the delivery method. Hence an instrumental variable IV is also required which predicts C-sections but does not affects outcomes directly. This is the approach taken in the next chapter.

Appendix A: Additional tables and figures

Table (A4.1) Descriptive statistics patients' characteristics for analytical sample 1

	Mean	SD
CONTROL VARIABLES		
Patient's characteristics		
Patient's age (in years)	25.65	6.73
Delivery before	0.06	0.24
Length of stay (in days) before delivery	0.35	1.66
Gestational hypertension	0.04	0.19
Pre-eclampsia	0.05	0.23
Haemorrhage in early pregnancy	0.02	0.14
Diabetes mellitus in pregnancy	0.01	0.12
Maternal care for other conditions	0.03	0.18
Multiple gestation	0.00	0.07
Known or suspected malpresentation of fetus	0.04	0.19
Known or suspected disproportion	0.04	0.20
Known or suspected abnormality of pelvic organs	0.10	0.30
Known or suspected fetal abnormality and damage	0.00	0.07
Known or suspected fetal problems	0.05	0.22
Polyhidrammios	0.01	0.10
Disorders of amniotic fluid and membranes	0.02	0.13
Premature rupture of membranes	0.01	0.12
Placental disorders	0.02	0.16
Placenta praevia	0.01	0.10
False labour	0.07	0.26
Prolonged pregnancy	0.01	0.09
Infectious and parasitic diseases classifiable elsewhere	0.01	0.10
Observations	31754	

Note: Means and standard deviations (SD). Analytical sample 1, 31754 deliveries on Sundays in 14 maternity units with surgical capabilities.

Table (A4.2) Descriptive statistics patients' characteristics for analytical sample 2

	Mean	SD
CONTROL VARIABLES *Patient's characteristics*		
Patient's age (in years)	25.63	6.60
Delivery before	0.06	0.24
Length of stay (in days) before delivery	0.30	1.53
Gestational hypertension	0.03	0.17
Pre-eclampsia	0.05	0.21
Haemorrhage in early pregnancy	0.02	0.13
Diabetes mellitus in pregnancy	0.01	0.11
Maternal care for other conditions	0.03	0.17
Multiple gestation	0.00	0.06
Known or suspected malpresentation of fetus	0.03	0.17
Known or suspected disproportion	0.03	0.18
Known or suspected abnormality of pelvic organs	0.08	0.27
Known or suspected fetal abnormality and damage	0.00	0.06
Known or suspected fetal problems	0.05	0.21
Polyhidrammios	0.01	0.09
Disorders of amniotic fluid and membranes	0.01	0.12
Premature rupture of membranes	0.01	0.11
Placental disorders	0.02	0.14
Placenta praevia	0.01	0.09
False labour	0.06	0.25
Prolonged pregnancy	0.01	0.09
Infectious and parasitic diseases classifiable elsewhere	0.01	0.11
Observations	39477	

Note: Means and standard deviations (SD). Analytical sample 2, 39754 child deliveries on Sundays in 50 maternity units.

Table (A4.3) OLS regression: dependant variable co-morbidity of the pregnancy period against ratio obstetricians/child deliveries

	(1) Prov. 1 β/(SE)	(2) Prov. 2 β/(SE)	(3) Prov. 3 β/(SE)	(4) Prov. 4 β/(SE)	(5) Prov. 5 β/(SE)	(6) Prov. 6 β/(SE)	(7) Prov. 7 β/(SE)	(8) Prov. 8 β/(SE)	(9) Prov. 9 β/(SE)	(10) Prov. 10 β/(SE)	(11) Prov. 11 β/(SE)	(12) Prov. 12 β/(SE)	(13) Prov. 13 β/(SE)	(14) Prov. 14 β/(SE)
Hypertension (ICD O13)	0.005	−0.007	0.045	0.013	0.014	0.012	0.004	−0.004	−0.013	0.019	0.022	−0.016	−0.039	−0.032
	(0.009)	(0.006)	(0.042)	(0.011)	(0.021)	(0.009)	(0.029)	(0.016)	(0.013)	(0.056)	(0.016)	(0.018)	(0.031)	(0.022)
Pre-eclampsia (O14)	0.028*	−0.027	−0.029	0.096**	0.037	−0.088**	0.062	−0.061	−0.038	0.041	0.006	−0.015	−0.030	0.022
	(0.016)	(0.026)	(0.023)	(0.040)	(0.028)	(0.041)	(0.043)	(0.047)	(0.030)	(0.031)	(0.024)	(0.036)	(0.024)	(0.024)
Haemorrhage (O20)	0.027	−0.002	−0.006	−0.010	−0.018	−0.017	−0.018	0.007	0.058*	0.016	−0.001	0.003	0.001	0.000
	(0.016)	(0.016)	(0.018)	(0.012)	(0.014)	(0.031)	(0.026)	(0.024)	(0.030)	(0.017)	(0.021)	(0.020)	(0.010)	(0.016)
Diabetes mellitus (O24)	0.009	0.005	−0.010	−0.004	0.001	0.000	0.012	0.017	−0.012	0.029	−0.021	0.029	0.006	0.011
	(0.008)	(0.009)	(0.016)	(0.011)	(0.012)	(.)	(0.023)	(0.022)	(0.009)	(0.031)	(0.014)	(0.019)	(0.014)	(0.013)
Maternal care (O26)	−0.019	0.004	−0.005	−0.036**	0.010	0.004	−0.067*	0.091**	0.042	−0.012	−0.010	−0.010	0.004	−0.018
	(0.017)	(0.030)	(0.010)	(0.017)	(0.015)	(0.014)	(0.034)	(0.041)	(0.028)	(0.014)	(0.027)	(0.017)	(0.019)	(0.018)
Multiple gestation (O30)	0.001	−0.004	0.006	−0.002	−0.011	0.007	0.001	0.018	0.008	−0.009	−0.018*	−0.002	0.001	0.021*
	(0.001)	(0.010)	(0.009)	(0.002)	(0.010)	(0.010)	(0.005)	(0.013)	(0.013)	(0.010)	(0.010)	(0.009)	(0.010)	(0.012)
Malpresentation (O32)	−0.001	−0.003	−0.005	0.030	0.016	0.033	−0.001	−0.033	0.048	−0.043***	−0.028	−0.018	0.004	−0.023
	(0.030)	(0.022)	(0.029)	(0.025)	(0.033)	(0.025)	(0.033)	(0.029)	(0.034)	(0.015)	(0.018)	(0.033)	(0.020)	(0.019)
Disproportion (O33)	0.054	0.008	−0.040	−0.029	0.047	−0.065	−0.087*	0.019	−0.001	0.009	0.003	0.059	−0.055*	−0.014
	(0.034)	(0.021)	(0.038)	(0.028)	(0.038)	(0.042)	(0.047)	(0.032)	(0.024)	(0.020)	(0.022)	(0.039)	(0.030)	(0.021)
Abnormality [pelvic] (O34)	0.027	0.068*	0.075	0.025	0.079	−0.011	0.028	−0.035	0.020	0.037	0.048	−0.026	0.062	0.011
	(0.031)	(0.039)	(0.054)	(0.034)	(0.053)	(0.044)	(0.044)	(0.034)	(0.056)	(0.036)	(0.039)	(0.038)	(0.041)	(0.034)
Fetal abnormality (O35)	−0.004	0.000	0.004	−0.001	0.004	0.000	−0.005	0.012	−0.012	−0.001	−0.005	0.007	0.003	0.001
	(0.011)	(.)	(0.004)	(0.001)	(0.008)	(.)	(0.011)	(0.011)	(0.012)	(0.002)	(0.007)	(0.009)	(0.005)	(0.015)
Fetal problems (O36)	−0.023	−0.018	0.043	0.010	0.006	−0.041	0.074	0.042	0.067**	−0.024	−0.005	−0.026	−0.000	−0.012
	(0.015)	(0.019)	(0.044)	(0.015)	(0.042)	(0.041)	(0.047)	(0.038)	(0.029)	(0.017)	(0.021)	(0.035)	(0.019)	(0.029)
Polyhidrammios (O40)	−0.006	0.007	−0.015	−0.012	−0.002	0.009	0.003	0.021**	−0.011	−0.016	0.002	−0.004	0.010	0.012
	(0.006)	(0.009)	(0.010)	(0.009)	(0.014)	(0.012)	(0.013)	(0.009)	(0.013)	(0.010)	(0.011)	(0.025)	(0.009)	(0.011)
Amniotic fluid (O41)	0.011	0.002	−0.002	−0.014	0.041**	0.037**	0.001	0.034**	−0.016	0.028	0.000	0.001	−0.003	−0.016
	(0.011)	(0.017)	(0.011)	(0.011)	(0.020)	(0.017)	(0.019)	(0.016)	(0.011)	(0.025)	(0.018)	(0.032)	(0.007)	(0.017)
Rupture of membranes (O42)	0.001	0.022*	0.008	0.010	0.012	−0.001	−0.002	0.024	−0.035*	0.003	0.029	−0.005	0.004	−0.026*
	(0.012)	(0.012)	(0.018)	(0.022)	(0.020)	(0.007)	(0.011)	(0.024)	(0.021)	(0.022)	(0.019)	(0.008)	(0.015)	(0.014)
Placental disorders (O43)	−0.016	0.003	0.006	−0.022	−0.005	−0.012	0.007	−0.024	−0.022	−0.005	−0.022**	−0.005	0.016	0.013
	(0.022)	(0.028)	(0.005)	(0.023)	(0.016)	(0.009)	(0.012)	(0.024)	(0.018)	(0.020)	(0.011)	(0.018)	(0.019)	(0.024)
Placenta praevia (O44)	−0.000	0.003	0.019	−0.002	−0.010	0.020	0.030	0.028*	−0.008	0.004	0.009	−0.003	0.018	−0.007
	(0.005)	(0.006)	(0.014)	(0.007)	(0.018)	(0.017)	(0.021)	(0.015)	(0.014)	(0.011)	(0.014)	(0.010)	(0.020)	(0.013)
False labour (O47)	0.003	0.020	−0.010	−0.003	0.001	0.087*	0.009	−0.004	−0.001	−0.007	0.021	−0.016	0.009	−0.057
	(0.025)	(0.019)	(0.037)	(0.022)	(0.027)	(0.049)	(0.032)	(0.020)	(0.032)	(0.035)	(0.031)	(0.032)	(0.020)	(0.045)
Prolonged pregnancy (O48)	0.003	0.013	0.014	−0.008	0.018	−0.009	−0.003	−0.004	−0.012	−0.011*	0.009	−0.003	−0.006	0.006
	(0.009)	(0.018)	(0.018)	(0.006)	(0.021)	(0.009)	(0.004)	(0.007)	(0.008)	(0.006)	(0.009)	(0.007)	(0.019)	(0.009)
Parasitic diseases (O98)	0.000	−0.005	0.006	0.000	−0.005	0.000	0.007	0.002	0.005	−0.014**	0.010	−0.011	0.008	−0.023*
	(.)	(0.008)	(0.005)	(0.004)	(0.005)	(0.005)	(0.027)	(0.019)	(0.006)	(0.006)	(0.019)	(0.009)	(0.020)	(0.012)

Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parentheses. Within provider bivariate regression, dependant variable each of the 19 individual co-morbidity listed regressed against the ratio of obstetricians/deliveries. There are 266 regressions in total.

Table (A4.4) Regression results with change in functional form of iteration between estimated C-section risk and the ratio of obstetricians/child deliveries

	(1) lineal 1 Marg. eff.	(2) lineal 2 Marg. eff.	(3) squared Marg. eff.	(4) squared Marg. eff.	(5) cubic Marg. eff.	(6) cubic Marg. eff.	(7) 4th Marg. eff.	(8) 4th Marg. eff.
Average marginal effect								
Ratio obstetricians/child deliveries	0.142***	0.086***	0.141***	0.086***	0.142***	0.087***	0.138***	0.084***
	(0.016)	(0.018)	(0.016)	(0.018)	(0.016)	(0.018)	(0.016)	(0.018)
Marginal effect at health status values								
Ratio obstetricians/child deliveries $\times$ $\hat{h}_i$=0.2	0.125***	0.073***	0.093***	0.052**	0.077**	0.040	0.056	0.018
	(0.019)	(0.020)	(0.022)	(0.024)	(0.030)	(0.031)	(0.035)	(0.035)
Ratio obstetricians/child deliveries $\times$ $\hat{h}_i$=0.3	0.140***	0.085***	0.158***	0.099***	0.167***	0.107***	0.175***	0.115***
	(0.016)	(0.018)	(0.017)	(0.019)	(0.020)	(0.021)	(0.020)	(0.022)
Ratio obstetricians/child deliveries $\times$ $\hat{h}_i$=0.4	0.155***	0.096***	0.197***	0.127***	0.207***	0.136***	0.212***	0.137***
	(0.019)	(0.020)	(0.025)	(0.026)	(0.030)	(0.030)	(0.031)	(0.032)
Ratio obstetricians/child deliveries $\times$ $\hat{h}_i$=0.5	0.170***	0.107***	0.211***	0.134***	0.211***	0.136***	0.202***	0.123***
	(0.025)	(0.026)	(0.032)	(0.033)	(0.034)	(0.034)	(0.038)	(0.038)
Ratio obstetricians/child deliveries $\times$ $\hat{h}_i$=0.6	0.185***	0.119***	0.199***	0.121***	0.192***	0.117***	0.169***	0.098**
	(0.033)	(0.033)	(0.038)	(0.038)	(0.039)	(0.040)	(0.041)	(0.041)
Ratio obstetricians/child deliveries $\times$ $\hat{h}_i$=0.7	0.200***	0.130***	0.161***	0.088*	0.162***	0.090**	0.129**	0.070
	(0.042)	(0.042)	(0.048)	(0.048)	(0.049)	(0.049)	(0.053)	(0.053)
Ratio obstetricians/child deliveries $\times$ $\hat{h}_i$=0.8	0.215***	0.141***	0.098	0.035	0.136*	0.064	0.089	0.035
	(0.051)	(0.050)	(0.067)	(0.065)	(0.071)	(0.071)	(0.080)	(0.079)
Ratio obstetricians/child deliveries $\times$ $\hat{h}_i$=0.9	0.230***	0.153**	0.009	−0.038	0.126	0.049	0.046	−0.029
	(0.061)	(0.059)	(0.095)	(0.093)	(0.126)	(0.127)	(0.129)	(0.129)
Patient's characteristics	yes	yes	yes	yes	yes	yes	yes	yes
Maternity unit dummies	yes	yes	yes	yes	yes	yes	yes	yes
Staff dummies	no	yes	no	yes	no	yes	no	yes
Observations	31754	31592	31754	31592	31754	31592	31754	31592

Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parentheses. Columns (1) and (2) present the marginal effect of a linear interaction of the ratio obstetricians/child deliveries with the predicted C-section risk. Columns (3) and (4) the marginal effects of the full quadratic interactions, progressively increasing, in the following columns, up to the quartic full interaction presented in columns (7) and (8).

Table (A4.5) Regression results using number of obstetricians and number of child deliveries grouped in categorical variables

	(1)	(2)	(3)	(4)
Number of obstetricians per day/maternity unit				
Number of obstetricians per day 1 (<3 obstetricians)	Ref.	Ref.	Ref.	Ref.
Number of obstetricians per day 2 (3-4 obstetricians)	0.048***	0.029***	0.038***	0.028***
	(0.008)	(0.009)	(0.009)	(0.009)
Number of obstetricians per day 3 (5-6 obstetricians)	0.081***	0.052***	0.065***	0.050***
	(0.009)	(0.010)	(0.010)	(0.010)
Number of obstetricians per day 4 (7-8 obstetricians)	0.113***	0.052***	0.079***	0.047***
	(0.012)	(0.013)	(0.013)	(0.013)
Number of obstetricians per day 5 (9-10 obstetricians)	0.168***	0.103***	0.121***	0.095***
	(0.016)	(0.019)	(0.019)	(0.020)
Number of obstetricians per day 6 (>10 obstetricians)	0.145***	0.076***	0.098***	0.066***
	(0.015)	(0.020)	(0.021)	(0.021)
Child deliveries per day/maternity unit				
Child deliveries per day 1 (<6 deliveries)	Ref.	Ref.	Ref.	Ref.
Child deliveries per day 2 (6-10 deliveries)	−0.041***	−0.016	−0.026**	−0.014
	(0.009)	(0.010)	(0.011)	(0.010)
Child deliveries per day 3 (11-15 deliveries)	−0.067***	−0.039***	−0.055***	−0.038***
	(0.010)	(0.012)	(0.012)	(0.012)
Child deliveries per day 4 (16-20 deliveries)	−0.106***	−0.072***	−0.088***	−0.069***
	(0.011)	(0.014)	(0.014)	(0.014)
Child deliveries per day 5 (>20 deliveries)	−0.119***	−0.059***	−0.099***	−0.057***
	(0.014)	(0.017)	(0.017)	(0.017)
Patient's characteristics	yes	yes	yes	yes
Monthly and yearly dummies	yes	yes	yes	yes
Maternity unit dummies	no	no	yes	yes
Staff dummies	no	yes	no	yes
Observations	31754	31592	31754	31592

Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parentheses. In this table the number of obstetricians and child deliveries are grouped in separate categorical variables. Columns (1) presents the regression results with no interaction with women's C-section risk, including patient's characteristics and monthly and yearly dummies. Column (2) add Staff dummies. Columns (3) and (4) present the same results of the previous two columns adding maternity unit dummies.

Table (A4.6) C-section rates (0-1) by groups of predicted women's C-section risk ($\hat{h}_i$) and by five quantiles of the ratio of obstetrician/child deliveries

Group	$\hat{h}_i$ values	obstetricians/child deliveries					Total
		q1	q2	q3	q4	q5	
1	$\hat{h}_i$ < 0.20	0.19	0.17	0.14	0.18	0.24	0.18
2	0.20≤ $\hat{h}_i$ <0.30	0.20	0.23	0.25	0.27	0.29	0.25
3	0.30≤ $\hat{h}_i$ <0.40	0.33	0.36	0.39	0.40	0.44	0.38
4	0.40≤ $\hat{h}_i$ <0.50	0.46	0.46	0.44	0.43	0.54	0.47
5	0.50≤ $\hat{h}_i$ <0.60	0.51	0.64	0.55	0.55	0.54	0.56
6	0.60≤ $\hat{h}_i$ <0.70	0.64	0.63	0.66	0.64	0.75	0.66
7	0.70≤ $\hat{h}_i$ <0.80	0.64	0.65	0.57	0.73	0.73	0.66
8	$\hat{h}_i \geq$ 0.80	0.69	0.76	0.64	0.76	0.91	0.76
Total		0.24	0.29	0.31	0.32	0.36	0.31

Note: The C-section risk $\hat{h}_i$ is estimated as the probability of C-sections using the results in Table 4.4.

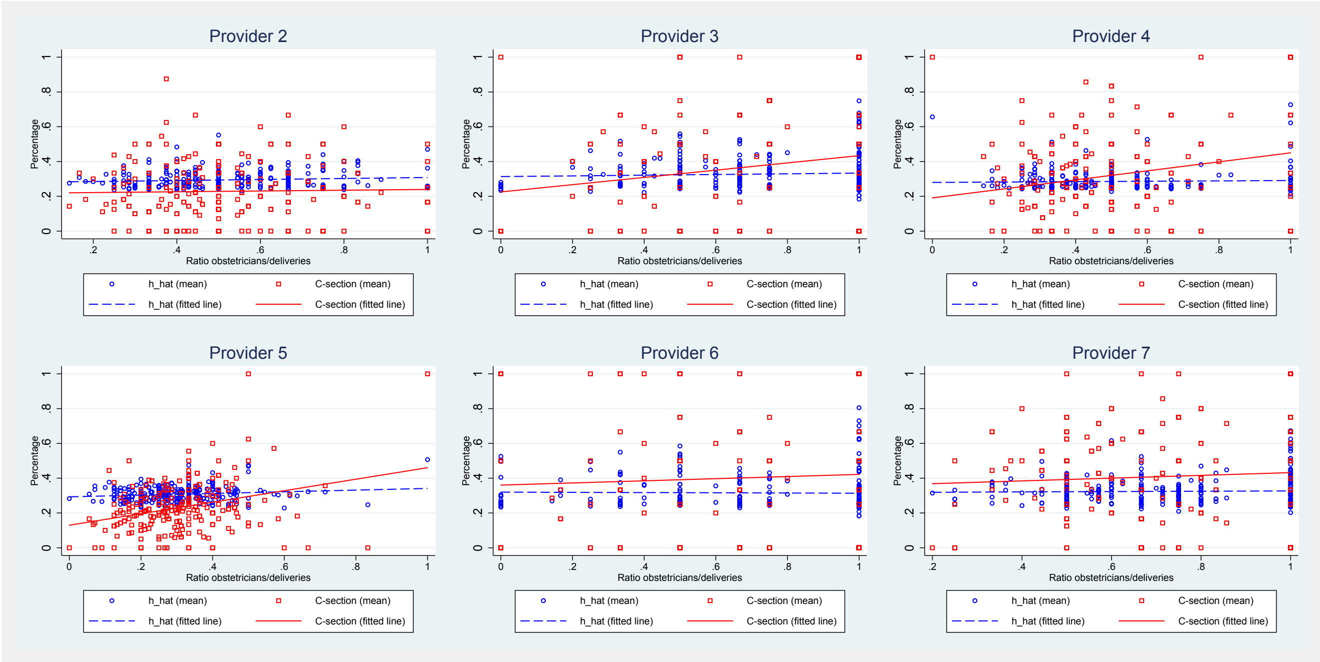

Figure (A4.1) Ratio obstetricians/volume of child deliveries and C-section rates and women's health risk of C-sections predicted with a logistic regression using antenatal care co-morbidities by provider part 1

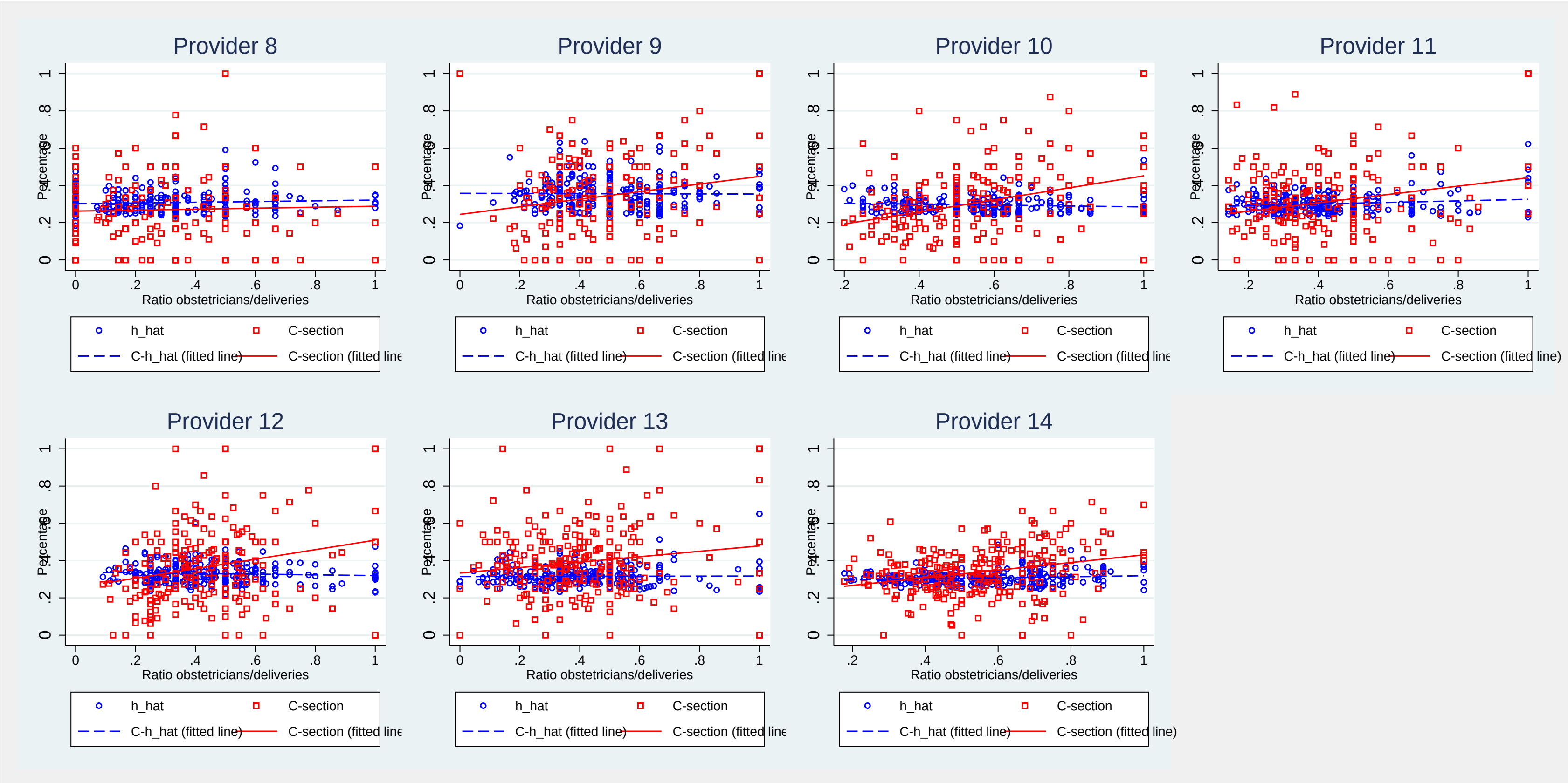

Figure (A4.2) Ratio obstetricians/volume of child deliveries and C-section rates and women's health risk of C-sections predicted with a logistic regression using antenatal care co-morbidities by provider part 2

Chapter 5

Do caesarean-sections affect maternal health outcomes?

5.1 Introduction

Caesarean section (C-section) rates are increasing in most countries (Betrán et al., 2016a; Chen, 2013). The World Health Organization (WHO) (World Health Organization, 2015) states that C-section rates higher than 10% are not associated with reductions in maternal and newborn mortality rates, and that C-section effects on maternal health outcomes are unclear. Therefore WHO recommends to perform C-sections only for medically indicated reasons.

There are many channels that can explain the rise of C-sections, and on the demand side, increasing medicalisation in childbirth means that highly interventionist procedures are being perceived as normal (Johanson et al., 2002). This can affect women's perceptions of quality of care at delivery and their choice. Usually a provider's structural quality and their C-section rates are positively correlated, so that women who value quality at delivery can trade-off continuity of care with local providers for the prospect of better delivery quality. I discuss this in Chapter 2. On the supply side, obstetricians are gaining skills and improving the safety of C-section procedures (Ecker and Frigoletto, 2007). But also obstetricians can perform C-sections due to convenience as studied in Chapter 4 where I show that in Lima a variation of obstetricians per child delivery inside each provider can influence C-section rates in low C-section risk women and lead to upcoding. Then the "medically indicated reason" is defined by the very obstetricians who interpret, diagnose and perform C-sections.

Together Chapter 2 and Chapter 4 examine the reasons for women to choose high structural quality obstetrician-led providers, and for obstetricians to perform C-section in low C-section risk, relatively healthy, women. Since there is a gap in understanding the direct effect of C-sections on mothers and babies, this chapter contributes to the literature examining the effect of C-sections on mothers' health outcomes.

Previous literature has only used a small number of maternal health outcomes. In contrast, I have information on all ICD10 codes[1] covering complications of delivery (O70-O75), related to the puerperium (O85-O90) and maternal death (O95-O96). The dataset also has rich information on mothers including morbidity, up to 280 days before delivery. I use information on difference in distance (in Km) from women to the nearest high C-section performer (tertiary hospital)

[1]ICD10: International Statistical Classification of Diseases and Related Health Problems 10th Revision.

and from women to the nearest midwife-led provider as an instrumental variable to generate exogenous variation in the probability of a C-section. I find that C-sections impact on women's health outcomes, especially in increasing haemorrhages, which is one of the main causes of maternal mortality, along with increasing sepsis and puerperal infections.

Section 5.2 briefly summarises and discusses the previous literature, especially papers employing instrumental variables methods. Section 5.3 presents the empirical approach using instrumental variables as the identification strategy. Section 5.4 contains the results which are discussed in Section 5.5.

5.2 Selective literature review

In this section I is present a short review of the clinical and economics literature on the effect of C-sections.

5.2.1 Clinical literature

There are few randomised controlled trials (RCTs) that study the health effects of C-sections for mothers. López-Zeno et al. (1992) show that active management, implemented as a one hour delay in the decision to perform C-sections, reduced maternal infections. Frigoletto Jr et al. (1995) find that active management, with one-to-one nurse care support among other measures, did not affect the rate of C-sections. More recently Gimovsky and Berghella (2016) found that extending the length of labour can reduce the rate of C-sections without affecting mother health outcomes.

Common to this literature is the selection of low risk women willing to take part in an experiment. This is because it is ethically controversial to randomly assign the treatment of C-sections and vaginal deliveries to high risk women. I seek to understand the effect of C-sections on all women (low and high risk) by using instrumental variable methods to mimic randomisation to C-sections.

Most of the clinical literature has examined the association of C-sections and health outcomes in observational studies (Villar et al., 2006; Lumbiganon et al., 2010; Souza et al., 2010; Hirayama et al., 2012; Keag et al., 2018). The basic problem with this approach is that health outcomes and the likelihood of a C-section can both be affected by confounding unobserved factors. For example, a planned C-section is recommended for women diagnosed with placenta praevia (National Institute for Health and Care Excellence - NICE, 2011), but placenta praevia also increases the risk of health complications (Fan et al., 2017), making it difficult to identify the effect of C-sections on maternal health outcomes if placenta praevia is not recorded in the dataset.

5.2.2 Economics literature

Some studies by economists have used a variety of strategies to identify the effect of C-sections in observational data. These include using choices by mothers who are physicians (Johnson and Rehavi, 2016), measures of physicians' skills that affects C-sections (Currie and MacLeod, 2017), and distances to low and high C-section rate providers (Card et al., 2019).

Johnson and Rehavi (2016) shows that mothers who are physicians or are partners of physicians have fewer C-sections than the rest of the population. They analysed 494,077 non physician and 2,766 physician mothers in California. Physicians had a 7.5% smaller probability of a C-section, and for physicians with relevant specialist knowledge the probability was 12.7% smaller.

The probability of lacerations and infections were 1.15% smaller for physicians but there was no difference in the probability of haemorrhage. But the direct effect of C-sections on health outcomes is not identified, because it is plausible that physician-mothers will receive better care from their medical colleagues and thy are likely to be able to detect potential complications and have them treated earlier.

Currie and MacLeod (2017) relied on market-level measures of skills as instrumental variables to identify individual physician's skills effect on C-section and health outcomes. The market is defined by geographical criteria and the skills are either surgical skills, measured as complications after a surgical procedure, or diagnostic skills, measured as appropriateness in recommending C-sections. Then they identify the effect of skills on C-sections and health outcomes. They use bleeding, fever and seizures at delivery and infection and bleeding following surgery as maternal outcomes. They also use neonatal distress, birth injury and neonatal death as infant outcomes. They found that a one standard deviation increase in diagnostic skills reduce the likelihood of a C-section by 16% for lower risk women and increase the likelihood of C-section by 3.4% for high risk women. Currie and MacLeod focus on the effect of diagnostic skills on C-sections and the effect of diagnostic skills on health outcomes but do not identify the direct effect of C-Sections on health outcomes.

Card et al. (2019), focused on the effect of C-section on low-risk first births, using the distance to low and high C-section providers as instrumental variables. Their sample was 491,604 mothers from California between 2007 and 2011. They estimated the effect of a C-section with 2SLS and found that C-sections reduce trauma to perineum and vulva during labour and perineal laceration.

Like Card et al. (2019) I also use distances to providers with different C-section rates as instruments, but instead of using actual, and so rather endogenous, C-section rates to define low and high C-section providers, I use the official administrative classification of providers based on their infrastructure and staff by the Health Ministry of Peru. And instead of identifying the effect on low risk women alone I intend to identify the effect on the whole population of mothers. Another difference is that I use a broader set of health outcomes rather than the less serious trauma to perineum and vulva.

My study improves on previous work in that I examine the effect of C-sections on a broader number of outcomes of importance. In this sense this study is similar to Johnson and Rehavi (2016) in the inclusion of health outcomes and to Currie and MacLeod (2017) in the identification of heterogeneity of C-sections in low and high risk women.

In summary this Chapter, improves on previous literature, in that it focuses on identifying the effect of C-sections on health outcomes, which include high risk along with low risk women, and considers the most important set of maternal health outcomes.

5.3 Empirical specification and identification strategy

5.3.1 Health outcomes

For health outcomes I use information on maternal complications of birth based on data from the time of the delivery up to 28 days after discharge. The diagnoses are classified in five groups, according to their severity and importance:

- Maternal death (O95 and O96)
- Postpartum haemorrhage (O72)

- Puerperal sepsis (O85)
- Other puerperal infections (O86)
- Perineal laceration of second, third and fourth degree (ICD codes O70.1, O70.2 and O70.3)

I use actual maternal death as the first maternal health outcome in this study. This differs from other studies, where for example, Sandall et al. (2018) use severe acute maternal morbidity (SAMM) which includes obstetric shock, cardiac arrest, acute renal failure and assisted ventilation as proxies of maternal mortality. Apart from maternal death, I include its main causes which are, in order of importance, haemorrhage and sepsis, as the second and third maternal health outcome in this study. A recent World Health Organization's systematic review states that the main cause of maternal death in the Latin American countries is haemorrhage (22.8%), followed by hypertension (22.1%), abortion (9.9%) and sepsis (8.3%) (Say et al., 2014). As hypertension and abortion cannot be caused by C-sections, I do not consider these cases in this study, instead I control for hypertension in the pregnancy period and I exclude all cases of abortion from the analytical sample.

Sepsis and infections are related and as such needed a systematic review and an international consultation before the World Health Organization arrived at this consensus definition "*Maternal sepsis [is] a life-threatening condition defined as organ dysfunction resulting from infection during pregnancy, child-birth, post-abortion, or [the] post-partum period*" (Bonet et al., 2017), The reader will note that an infection can be followed by a sepsis.

In a previous WHO systematic analysis for maternal mortality, both sepsis and infections, were included together (Khan et al., 2006), possibly because it was difficult to distinguish between them in the context of lack of accurate records in lower and middle income countries. As sepsis is a more serious condition than infections, I include puerperal infections in the fourth place of importance in the set of maternal health outcomes. I include perineal laceration in the analysis mainly for comparative reasons because it was used in previous medical (Villar et al., 2006) and economic literature (Johnson and Rehavi, 2016; Card et al., 2019).

I do not evaluate the effect of C-sections on child health outcomes. This is because the Health Ministry of Peru, due to the sensitive nature of the information, assigned an anonimised ID to each individual, so that it is not possible to link mothers to babies in the dataset.

5.3.2 The identification problem

I use administrative data from the Peruvian public health insurance programme described in the Introduction of this thesis, and have and analytical sample of 287,640 child deliveries with distance information.

Table 5.1 shows the overall C-section rate (33%) and maternal health outcomes. There is no difference between C-sections and vaginal delivery for maternal death, and for the other health outcomes, with the exception of perineal laceration, where the probability of complications is higher for C-sections. Note that as some outcomes are more frequent in C-sections and one, perineal laceration, more frequent in vaginal deliveries the accumulation of them in a composite indicator such as 'any complications' is less informative.

Panel (a) of Figure 5.1 shows the number of vaginal deliveries and C-sections by days of the week. The number of C-sections is smaller on Sundays. Obstetricians schedule elective C-sections for weekdays so that there are no elective C-section's on Sundays: all of them are emergencies. We might therefore expect more complications on Sundays (Palmer et al., 2015; Meacock et al., Table (5.1) Means and standard deviation of maternal health outcomes by mode of delivery

	All sample	C-sections	Vaginal delivery	Diff. means
Variable of interest				
C-section	0.330			
	(0.470)			
Outcome variables				
Maternal death	0.0001	0.0001	0.0001	0.0000
	(0.0112)	(0.0112)	(0.0112)	
Postpartum haemorrhage	0.0176	0.0322	0.0104	0.0218***
	(0.1313)	(0.1764)	(0.1012)	
Puerperal sepsis	0.0102	0.0206	0.0051	0.0155***
	(0.1005)	(0.1420)	(0.0712)	
Other puerperal infections	0.0390	0.0578	0.0297	0.0281***
	(0.1936)	(0.2334)	(0.1699)	
Perineal laceration and obstetric trauma	0.0045	0.0001	0.0067	−0.0066***
	(0.0670)	(0.0086)	(0.0815)	
Any complication	0.0664	0.1013	0.0491	0.0523***
	(0.2490)	(0.3019)	(0.2162)	
Observations	287,460	94,865	192,595	287,460

Note: Standard deviations in parentheses. Difference in means test * p<0.1, ** p<0.05, *** p<0.01. Any complication takes the value of 1 if in the presence of any of the 5 health outcomes and 0 otherwise

2017) but as panel (b) shows there are lower rates of three complications usually associated with C-sections on Sundays. I control for Sundays in the regression.

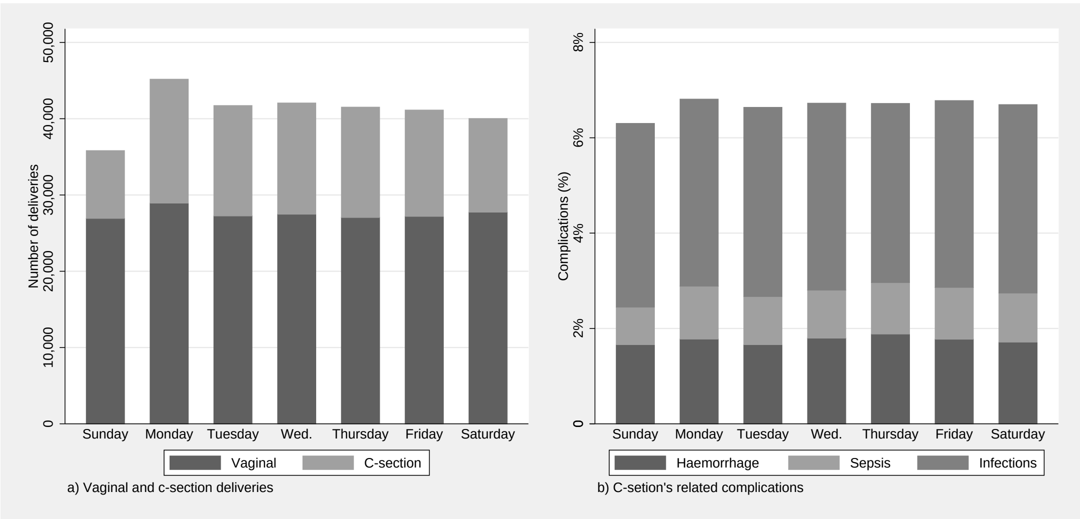

Figure (5.1) C-sections and maternal complications by day of week

Appendix Table A5.1, compares 22 pre-delivery covariates which may influence the likelihood of C-section and post-delivery outcomes[2]. This table shows, in general, that women who have more co-morbidities are more likely to give birth by C-sections.

Table A5.2 shows a selected number of women's co-morbidities as recorded at the time of delivery, which arguably are difficult to up-code. These will be used in the sensitivity analysis as an additional set of controls for co-morbidities. This table also shows that women with more co-morbidities are more likely to have C-sections.

[2]I use these covariates from the pre-delivery period in the main analysis because obstetricians can up-code co-morbidities of the delivery period to justify C-sections, as examined in Chapter 4 of this thesis.

Women who have a C-section are more likely to have co-morbidities and therefore more likely to have worse outcomes. We can control for these morbidities but there may be unobserved factors which affect C-section choice and outcomes: other unobserved morbidities, physician surgical skill, women and obstetricians preferences.

Figure 5.2 plots the proportions of C-sections and puerperal infections per month. The correlation between the first differences is 0.23, suggesting that C-sections are a candidate to explain this kind of infection. However there are other variables that could affect infections such as women with asymptomatic group B streptococcal bacterium (Pass et al., 1982), and although I control for a rich set of co-variates from the pre-delivery period, (detailed in Table A5.1 and in Table A5.2) I do not control for the presence of this bacterium due to data availability. Because of this a simple regression will likely suffer from omitted variable bias. As unobservable factors may affect both the probability of having a C-section and of having complications, I attempt to solve the identification problem by using instrumental variables (IVs) that affect the probability of C-sections and are not correlated directly with outcomes (Cameron and Trivedi, 2005; Angrist and Pischke, 2009).

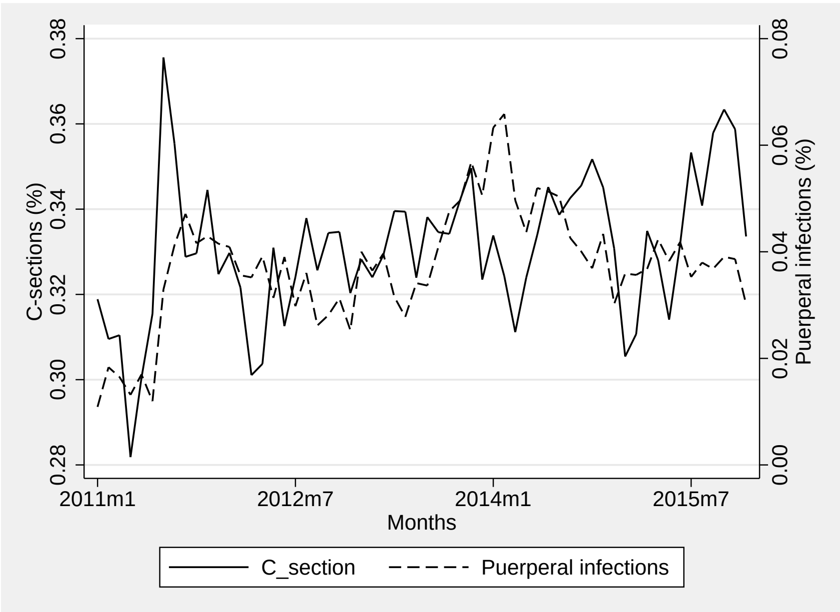

Figure (5.2) Percentage of c-sections and puerperal infections aggregated by month

5.3.3 Strength of IVs

I use an econometric model that incorporates distances as instrumental variables for identification purposes. There is a large literature in health economics on the use of distances as instruments following McClellan et al. (1994). Although distance actually travelled by patients are endogenous because sicker patients travel further for higher quality providers, patient distances to each provider are not endogenous (Gowrisankaran and Town, 1999), because distance between two geographical points are fixed and are not affected by health status or the actual choice of provider.

I propose to use as an instrumental variable the difference (in km) in the distance from a woman to the nearest high C-section performer and from her to the nearest midwife-led provider. I argue that it is possible to use distances to identify the effect of C-sections on health outcomes. Since the sample is women covered by a public insurance scheme and who are therefore not wealthy, there seems little risk that women will locate to be nearer their preferred provider.

Providers in Peru are officially classified according to their structural and organisational capabilities in primary, secondary and tertiary hospitals[3]. The instrumental variable uses the fact that different types of delivery providers have structural characteristics which affect the probability of C-sections. Thus unlike Card et al. (2019), I do not classify providers on the basis of their actual C-section rate, but by an administrative definition based on their facilities (Ministerio de Salud del Peru, 2004) as detailed in the thesis Introduction.

Table 5.2 reports the classification of providers into primary, secondary and tertiary levels, along with the volume of child deliveries and C-sections. Nine tertiary level providers perform 60% of child deliveries and 80% of C-sections. Midwife-led level I providers do not do C-sections since they do not have operating theatres.

Table (5.2) Child deliveries and C-sections by level of providers

	Providers	Delivery	% of deliveries	C-sections	% of C-sections	C-section rate
Level I	36	52,048	18%		0%	0
Level II	5	61,528	21%	18,809	20%	0.306
Level III	9	173,884	60%	76,056	80%	0.437
	50	287,460		94,865		0.330

I cannot compute distances from home to health facilities as home address is not recorded in the dataset and instead I use the address of the facility which was most frequently used by the women for non-antenatal and child-delivery care. This comes with a potential measurement error that is addressed in the discussion section of Chapter 2.

Providers are officially organised geographically in 10 networks and 45 micro-networks. Micro-network and network boundaries reflect geographical features, such as the existence of hills, rivers and transport connections and accounts for population and number of providers (Ministerio de Salud del Peru, 2001).

Networks are an aggregation of micro-networks and as such the differences in characteristics are stronger. For example there is a pronounced hill between San Juan de Lurigancho network and Tupac Amaru network, both in the north-east of Lima, so linear distances across networks alone do not reflect travel time. For this reason I use distances within networks to construct choice sets.

I use the same definition of a woman's choice set as in Chapter 2: I define a woman's child delivery choice set as that which includes the closest child delivery provider to each possible antenatal care choice set (details in chapter 2), the four closest maternity units level I-4 inside the network, the closest providers levels II-1 and II-2 inside the network, the four closest provider levels III-1 and the highest provider level III-2.

I use the following distances within a woman's child delivery choice set to construct the instrumental variable.

- Let D_i^M be distance from women to their nearest midwife-led maternity unit. This is the closest child delivery provider of level I, specifically the level I-4.

[3]There are in total 366 providers for maternal care, 50 equipped for child delivery. Providers are classified into three levels with eight sub-levels, all of them ordered from lowest to highest according to their structural capabilities and staffing. Level I contains four sub-groups: I-1, I-2, I-3 and I-4, level II has two sub-groups II-1 and II-2 and level III another two sub-groups, III-1 and III-2, and child deliveries are provided from level I-4 onwards. The level I-4 identifies midwife-led providers and levels II and III obstetrician-led providers. See introduction of the thesis for details.

- Let D_i^{III} be distance from women to their nearest obstetrician-led maternity unit of level III, which includes subcategories levels III-1 and III-2.

Then the instrumental variables is $Z_i = D_i^{III} - D_i^M$: the difference in distance from the woman to their closest obstetrician-led provider of level III (a high C-section performer) and from the women to the closest midwife-led provider of level I (where no C-sections can be performed). Moscelli et al. (2018) similarly use differential distance as an IV for choice of public versus private hospital.

The descriptive statistics of distances and instrumental variables and women's characteristics are presented in Table 5.3. The first line shows that on average, women who give birth by C-section have travelled an extra 1.13 km. Sicker women may be more likely to travel to better equipped providers, increasing both the likelihood of having a C-section and of poor health outcomes.

Table (5.3) Descriptive statistics for distances and instrumental variables

	All sample	C-sections	Vaginal delivery	Diff means
Distances				
Distance (in Km) travelled for delivery	5.014 (6.064)	5.769 (6.649)	4.642 (5.719)	1.127***
Distance (in Km) to nearest midwife-led provider	3.248 (3.212)	3.173 (3.098)	3.285 (3.266)	−0.112***
Distance (in Km) to nearest high C-section performer	6.288 (5.943)	5.890 (6.062)	6.484 (5.874)	−0.595***
Instrumental variables				
Difference (in Km) to high C-section performer and to midwife-led provider	3.047 (5.504)	2.725 (5.478)	3.206 (5.511)	−0.481***
Observations	287,460	94,865	192,595	287,460

Note: Means with standard deviations in parenthesis. Difference in means test * p<0.1, ** p<0.05, *** p<0.01. The instrumental variable is constructed as the difference in distance (in Km) from women to the nearest high C-section performer (tertiary hospital) and from women to the nearest midwife-led provider.

The second line of Table 5.3 shows that women who give birth by C-sections have, on average, a shorter travelling distance to the nearest midwife-led maternity unit than women who give birth by vaginal delivery. Comparison of the first and second lines in the third column of Table 5.3 suggests that women do not choose the closest midwife-led provider for vaginal delivery. As seen in Chapter 2 women who have a midwife-led maternity unit as the nearest provider, will bypass it in search of better quality and are exposed to a greater likelihood of having C-sections. This is not uniform, as we learn from Chapter 3: where women who are very close to a midwife-led maternity unit are encouraged to use its service with the shorter distance, especially women of lower risk health status.

The third line shows that women who give birth by C-sections have, on average, shorter distance to the nearest obstetrician-led provider of level III than women who give birth by vaginal delivery.

The last row shows that for women who have C-sections the extra distance to a high level (obstetrician-led) provider is smaller than for those who had vaginal delivery.

Contrasting the first and the third line of Table 5.3, the second column suggests that women who give birth by C-section have travelled, on average, nearly as much as the distance to the nearest level III provider[4].

But whilst higher level providers have higher C-section rates they also attract high risk pregnancies. Therefore the instrumental variable has the following characteristic. As there are more

[4]They travel slightly less than the nearest high C-section performer (level III) because there are other obstetrician-led providers (level II) that might be closer.

midwife-led providers officially classified as a lower level provider (36) compared with tertiary level providers (9), on average the distances from women to midwife-led maternity units are shorter than from women to level III.

I expect the differential distance instrument will predict the likelihood of having C-sections, and I estimate for women $i = 1, .., I$ the first stage regression

$$CS_i = Z_i \alpha z + X_i^{anc'} \alpha_x + \epsilon_i \tag{5.1}$$

$CS_i \in \{1, 0\}$ is an indicator for woman i having a C-section rather than vaginal delivery. Z_i is the instrumental variable $D_i^{III} - D_i^{M}$.

The X_i^{anc} are covariates including women's risk factors, as recorded in the pre-delivery period. (detailed in Table A5.1). X_i also include $Sunday_i \in \{0, 1\}$ as an indicator if women i gives birth on Sundays or not. ϵ_i is the error term. All X_i in all models include a constant term.

Table 5.4 presents the first stage regression results. The coefficient on the IV is negative and highly significant. The partial F-statistics of 102 is much higher than the conventional required value of 10 (Staiger and Stock, 1997). All control variables have the expected sign.

Figure 5.3 depicts a balancedness test on covariates. This is the results of lowess regressions (Cleveland, 1979), which is a locally weighted regression of covariates on the instrument. The two highest lines corresponds to the women's age and the predicted C-section risk, which can be interpreted as an average summary of women's co-morbidities. The almost flat series support the argument that the observed series conditioned on the IV are random, suggesting that this is also true for the unobserved variables affecting outcomes.

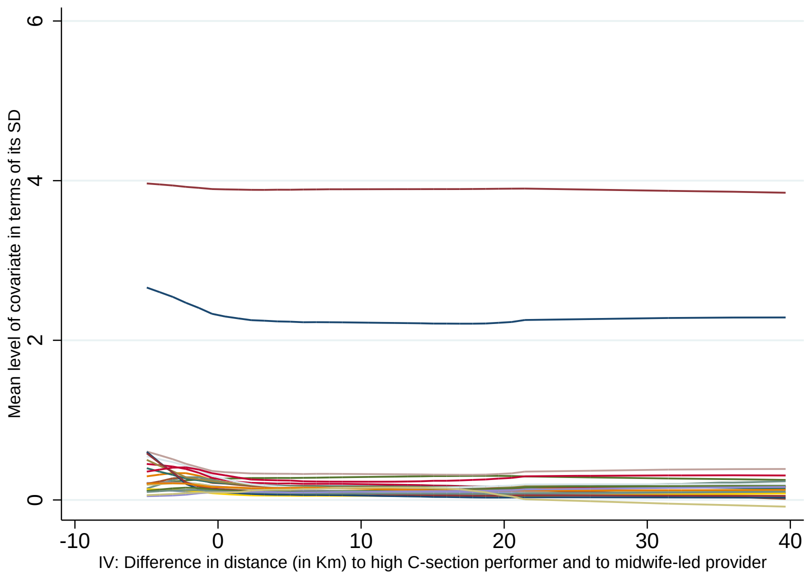

Figure (5.3) Balance in covariates due to IV

Note: This is the result of a lowess regression of covariates on the instrumental variable. The vertical axis is the mean level of covariates in terms of its standard deviation and the horizontal axis is measured in kilometres. I include all control variables in Table A5.1, plus the predicted C-section risk which is also a summary of health status using these covariates.

Table (5.4) First stage OLS regression results for probability of a C-section

	β/(SE)
Instrumental variables	
Difference (in Km) to high C-section performer and to midwife-led provider	−0.001***
	(0.000)
Control variables	
Age 1 (< 21 years)	−0.015***
	(0.002)
Age 2 (21 - 25 years)	−0.009***
	(0.002)
Age 3 (26 - 30 years)	Ref.
Age 4 (31 - 35 years)	0.012***
	(0.003)
Age 5 (> 35 years)	0.039***
	(0.003)
Delivery before	−0.038***
	(0.003)
Length of stay (in days) before delivery	0.016***
	(0.001)
Gestational hypertension	0.075***
	(0.005)
Pre-eclampsia	0.100***
	(0.004)
Haemorrhage in early pregnancy	0.014**
	(0.006)
Diabetes mellitus in pregnancy	0.054***
	(0.007)
Maternal care for other conditions	0.022***
	(0.005)
Multiple gestation	0.412***
	(0.010)
Known or suspected malpresentation of fetus	0.177***
	(0.005)
Known or suspected disproportion	0.173***
	(0.005)
Known or suspected abnormality of pelvic organs	0.448***
	(0.003)
Known or suspected fetal abnormality and damage	0.101***
	(0.013)
Known or suspected fetal problems	0.045***
	(0.004)
Polyhidrammios	0.094***
	(0.010)
Disorders of amniotic fluid and membranes	0.032***
	(0.007)
Premature rupture of membranes	0.019**
	(0.008)
Placental disorders	0.035***
	(0.006)
Placenta praevia	0.113***
	(0.009)
False labour	0.042***
	(0.003)
Prolonged pregnancy	0.055***
	(0.009)
Infectious and parasitic diseases classifiable elsewhere	0.005
	(0.007)
Delivery on Sunday	−0.074***
	(0.002)
Observations	287,460
Partial F-test (Instrumental variable)	101.53

Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parentheses.

5.3.4 Empirical specification for health outcomes and heterogeneity

The outcome equation is:

$$y_i = CS_i\beta_{cs} + X_i^{anc'}\beta_x + \zeta_i \tag{5.2}$$

Where $y_i \in \{1, 0\}$ is an indicator for woman i having a health complication at delivery or within 28 days of discharge. I control for the same covariates as in equation (5.1); ζ_i is the error term and β_{cs} is the coefficient of interest.

The equations (5.1) and (5.2) for the treatment and the outcomes can be estimated jointly by two stage least square (2SLS) using linear probability models or by a bivariate probit (BP) model. Rivers and Vuong (Rivers and Vuong, 1988) proposed the estimation of the bivariate probit model with instrumental variables by two-stage conditional maximum likelihood. Simulations suggest that maximum likelihood bivariate probit is preferred to the 2SLS, especially in larger samples and when the average probability of the dependant variable is close to zero or one (Bhattacharya et al., 2006; Terza et al., 2008; Chiburis et al., 2012). Consequently, in this chapter I use a bivariate probit estimated using Limited Information Maximum Likelihood (LIML) where the first equation is a reduced form, providing instruments for identification of the parameters in the second structural equation.

I expect differences in the estimation between 2SLS and LIML biprobit, since the former estimates Local Average Treatment Effect (LATE) and the latter the Average Treatment Effect (ATE) (Chiburis et al., 2012).

To investigate possible heterogeneity in the effect of C-sections on health outcomes by women's C-section risk, I propose re-writing equation (5.2) to include an interaction between the treatment, C-section, with an dummy variable indicator of low versus high C-section risk, a composite morbidity measure.

As in Chapter 4, I first estimate the following pooled logistic regression:

$$h(X_{i,\beta}^{anc}) = Pr(CS_i = 1/X_i^{anc}) = exp(X_i^{anc'}\beta)/[1 + exp(X_i^{anc'}\beta)] \tag{5.3}$$

Where $CS_i \in \{0, 1\}$ is an indicator for women i having a C-section and $X_i^{anc'}$ only contains the woman's characteristics (including age and pre-delivery morbidities in Table 5.4. I use the predicted probability of a C-section contidional on the woman's characteristics $\hat{h_i} = h(X_i^{anc}, \hat{\beta})$ as a summary measure of her underlying propensity to have a C-section, as in Currie and MacLeod (2017).

I then generate a dummy variable splitting the sample between low and high C-section risk measured as if their estimated probability is below or above 0.5.

Finally I estimate a new second stage regression, replacing the equation (5.2) in the estimation process, which includes the constructed dummy variable variable iterated with the indication of C-section as:

$$y_i = CS_i\beta_{cs} + CS_i * \hat{h}_i^{high}\beta_{csh} + X_i^{anc'}\beta_x + \zeta_i \tag{5.4}$$

where $\hat{h}_i^{high} \in \{1, 0\}$ is an indicator for woman i being either a high risk individual or a low risk individual. Note that β_{cs} is effect of C-sections on low risk women, $\beta_{cs} + \beta_{csh}$ the effect on high risk women.

I use the same estimation sample as in Chapter 4 to estimate (5.3), (see Table 4.4 in Chapter 4). This uses only women on Sundays on obstetrician-led maternity units and gives a cleaner prediction of C-section risk based only on women's characteristics on a day when there is no elective C-section which might be affected by women's preferences for C-sections . However I perform sensitivity analysis of the results using also the entire population of women.

Figure 5.4 shows the kernel density of the predicted women's exposure to vaginal delivery and C-section according to their estimated C-section propensity score $\hat{h}_i$.

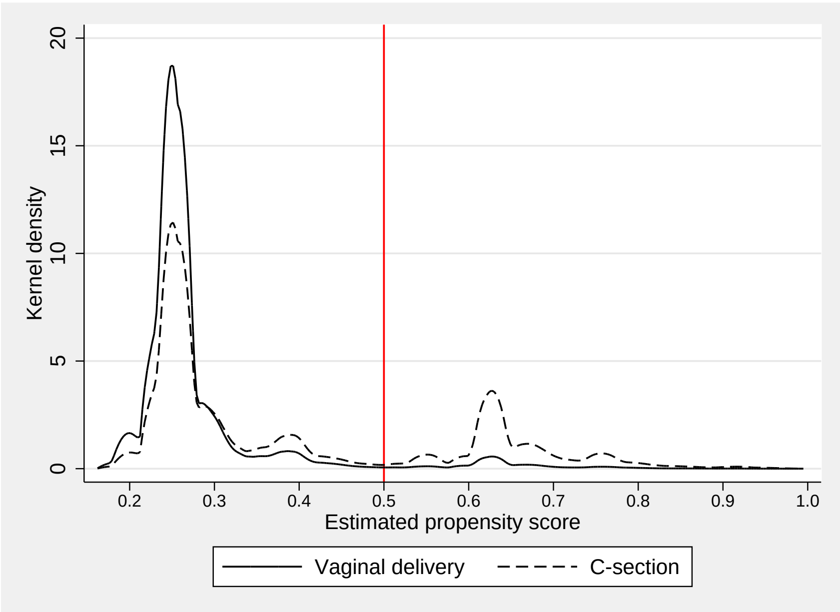

Figure (5.4) Kernel density of predicted women's health risk $\hat{h}_i$ by type of delivery

The vertical line splits the sample into low and high risk C-section exposure as their estimated probability is above or below 0.5. Low risk C-section exposure women had a C-section in 27% of the cases while 75% of high risk C-section's exposure women had a C-section.

The system of equations (5.1) and (5.2) are estimated by biprobit using limited information maximum likelihood. The system of equations (5.1) and (5.4) are estimated using limited information maximum likelihood with the user written Stata command 'cmp' (Roodman, 2011).

5.4 Results

The Table 5.5 reports estimates of the effect of C-section on five outcomes. The results are reported as the change in the probability of the outcome due to having a C-section averaged over all women (average marginal effect).

Column (1) has results estimated by probit. Column (2) reports the results estimated by biprobit with instrumental variables. I find that C-sections increases the occurrence of haemorrhage (by 2%), puerperal sepsis (by 1.3%) and puerperal infections (by 4.8%) and reduces perineal laceration (by 1.2%). I do not detect an effect on maternal mortality. So endogeneity of C-sections only seems to matter for puerperal infections and perineal lacerations, the two less serious complications from the set of outcomes included, it seems that only for these outcomes there are relevant unobserved women's characteristics not controlled for.

Table (5.5) Effect of C-section on maternal health outcomes

	(1) No IV Probit	(2) IV Biprobit
Maternal death	0.00001	−0.00001
	(0.0001)	(0.0001)
Haemorrhage	0.020***	0.020***
	(0.001)	(0.003)
Sepsis	0.014***	0.013***
	(0.0005)	(0.002)
Puerperal infection	0.025***	0.048***
	(0.001)	(0.014)
Perineal laceration	−0.017***	−0.012**
	(0.003)	(0.005)

Note: Coefficients are average marginal effects. * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parentheses. Patients characteristics included are listed in Table A5.1. The instrumental variable is difference (in km) from the woman to the nearest high C-section performer and from the woman to nearest midwife-led provider.

5.4.1 Heterogeneity of C-section effect on maternal outcomes by women's health risk

Next I examine if the effect of a C-section varies according to whether a woman has morbidities which increase the probability that she will have a C-section. I expect that most complications appear in high risk women, so arguably the potential effect on health of not performing a C-section on them would be higher. But in healthier women the contrary may occur, as they are not expected to have so many complications and C-section can worsen their outcomes.

Table 5.6 reports the estimation of equation (5.4): the average marginal effect of C-sections on the risks of complications estimated for women at low and high risk of C-section. The first line shows that there is no effect nor an heterogeneity of the effect of C-sections regarding maternal mortality. The outcomes in lines two to four show that, in general, the effects are higher for a low risk of C-section. For low C-section risk women having a C-section increases the probability of haemorrhage by 1.8% sepsis by 1.8% and puerperal infections by 9.1%. This contrast with the high risk of C-section group, for women in this group having a C-section does not have a statistical significant effect on the probability of haemorrhage, and increases the probability of sepsis by 1% and puerperal infections by 5.1%. So the detrimental effects of C-sections are higher for women at low risk of C-section for these health outcomes.

The last line shows that the reduction in the probability of suffering perineal laceration for those who have a C-section are only for low C-section risk women. But this comes at a cost of increased probability of haemorrhage, puerperal sepsis and puerperal infections. Overall performing C-sections on low risk women seems to be trading-off one complication for another.

Note that the point estimates for the average marginal effects, reported in the first column, differ from those reported for biprobit in Table 5.5. This is because I am imposing a slightly different functional form, but there is no difference in terms of their confidence intervals. As stated above in equation (5.4) β_{cs} is effect of C-sections on low risk women, $\beta_{cs} + \beta_{csh}$ the effect on high risk women and the average marginal effect is the average of both effects on all women.

Table (5.6) Heterogeneity on the effect of C-section on maternal health outcomes by women's risk of C-sections

	(1)	(2)	(3)
		C-Section risk	
	Average	Low	High
Maternal death	−0.0001	−0.00005	−0.0002
	(0.0001)	(0.0001)	(0.0004)
Haemorrhage	0.016**	0.018***	0.004
	(0.006)	(0.007)	(0.006)
Sepsis	0.017***	0.018***	0.009***
	(0.003)	(0.004)	(0.002)
Puerperal infection	0.086***	0.091***	0.051***
	(0.023)	(0.025)	(0.009)
Perineal laceration	−0.011**	−0.010***	−0.021
	(0.005)	(0.003)	(0.015)
Deliveries	287,460	252,059	35,401
C-section rate	33%	27.06%	75.33%

Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parentheses. Patients characteristics included are listed in Table A5.1 in the appendix. Women's C-section risk is estimated by logistic regression; C-section as dependant variable with patient's co-morbidities, low and high risk is defined if the predicted propensity of C-sections is greater or lower than 0.5 respectively.

5.4.2 Sensitivity analysis

The Table 5.7 reports sensitivity analysis estimates using two-stage least squares (2SLS) instrumental variable estimation compared with biprobit.

Table (5.7) Sensitivity analysis 2SLS and Biprobit, effect of C-sections on health outcomes

	(1)	(2)	3)	(4)
	OLS	Probit	2SLS	Biprobit
Maternal death	−0.000002	0.00001	0.001	−0.00001
	(0.0001)	(0.0001)	(0.001)	(0.0001)
Haemorrhage	0.023***	0.020***	0.074**	0.020***
	(0.001)	(0.001)	(0.030)	(0.003)
Sepsis	0.016***	0.014***	0.0003	0.013***
	(0.001)	(0.0005)	(0.021)	(0.002)
Puerperal infection	0.027***	0.025***	−0.003	0.048***
	(0.001)	(0.001)	(0.004)	(0.014)
Perineal laceration	−0.007***	−0.017***	−0.004	−0.012**
	(0.0002)	(0.003)	(0.017)	(0.005)

Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parentheses. Columns (1) and (2) no instrumental variables and column (3) and (4) instrumental variable regression results. Patients characteristics of the pre-delivery period included are listed in Table 5.3.

Column (1) has results from a linear probability model estimated by OLS. The results for haemorrhage, infections and sepsis are very close to those in column (2) estimated by probit. The results differ for maternal death, which are insignificant in both cases and with opposite signs, and for perineal laceration.

Column (3) is the instrumented regression, using the difference in distance from women to Level III and from women to Level I as instrumental variable, estimated by two stage least squares (2SLS) with linear probability models for the outcomes and having a C-section. We expect differences in the estimation between 2SLS and LIML biprobit in column (4) since the former estimates Local Average Treatment Effect (LATE) and the latter the Average Treatment Effect (ATE) (Chiburis et al., 2012). Results also differ when probabilities are close to 0 or 1 and most of our outcome probabilities are close to zero.

Figure 5.5 shows that the biprobit estimation's confidence interval lies inside the confidence interval estimated by 2SLS, supporting that both methods estimate statistically the same results, but biprobit behaves better in our case where the outcomes are close to zero.

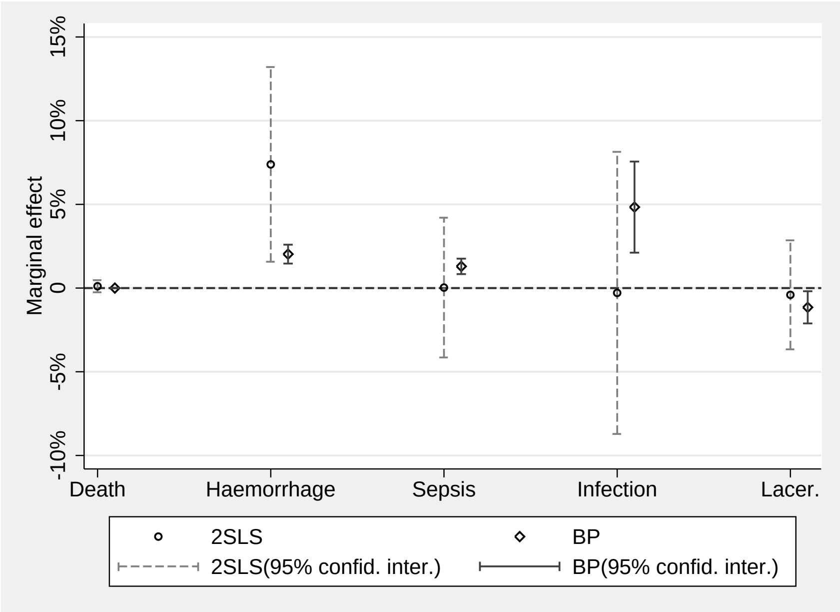

Figure (5.5) Two stage least square and bivariate probit estimations with confidence intervals

The Table 5.8 presents estimates of the effect of C-section on the same outcomes from two additional different specifications.

Column (1) reproduces the main results. Model (2) includes an additional set of co-morbiditites recorded at the time of child delivery, excluding a group of codes that are potentially upcodable (as explained in Chapter 4). The variables included are listed in Table A5.2 in the Appendix.

Model (3) includes the interaction between the distance to the nearest provider, regardless of the type, and the predicted co-morbidity. The idea is to control for the fact that women with higher co-morbidity can choose the closest provider at the time of delivery in case of an emergency, as is suggested in the literature (Moscelli et al., 2018).

Comparing the point estimates I find only slight differences, which confirms the robustness of the main results.

For performing sensitivity analysis on the heterogeneity by women's risk of C-sections, I perform several logistic regressions for equation (5.3) apart from the base line model. I consider co-morbidities of the pregnancy period on the full sample, and co-morbidities of the pregnancy period plus additional co-morbidities, reported in Table A5.2, on Sundays in obstetrician-led maternity units and on the full sample. The minimum cross correlation between the predicted C-section risk increasing the sample size and using more co-morbidities that I find is 0.80, signalling that the predicted C-section risks obtained are similar.

Table A5.3, presents the results for the logistic regression that contain the full sample with

Table (5.8) Sensitivity analysis for different specifications by bivariate probit, effect of C-sections on health outcomes

	(1)	(2)	(3)
Maternal health outcomes			
Maternal death	−0.00001	0.00002	0.00003
	(0.0001)	(0.0001)	(0.0001)
Haemorrhage	0.020***	0.018***	0.022***
	(0.003)	(0.002)	(0.003)
Sepsis	0.013***	0.018***	0.014***
	(0.002)	(0.003)	(0.002)
Puerperal infection	0.048***	0.044***	0.048***
	(0.014)	(0.014)	(0.017)
Perineal laceration	−0.012**	−0.012***	−0.011**
	(0.005)	(0.003)	(0.005)
INSTRUMENTAL VARIABLES	yes	yes	yes
COVARIATES			
Patient's co-morbidities of pregnancy period	yes	yes	yes
Sunday	yes	yes	yes
Patient's co-morbidities at time of delivery		yes	
Distance to nearest provider × predicted patient's co-morbidities			yes

Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parentheses. The Instrumental variable is difference (in Km) from women to the nearest high C-section performer and from women to nearest midwife-led provider. Patients characteristics of the pregnancy period included are listed in Table 5.3. Patients characteristics at the time of delivery included are reported in the Table A5.2 in the appendix

additional covariates, and the histograms of the predicted risk of C-sections by type of delivery are plotted in Figure A5.1 dividing the new high and low risk by the vertical line in 0.5. These show that predicted women's C-section risk does not change dramatically from the reduced sample in Sundays used in the main analysis.

Table A5.4 presents the results for equation (5.4) in a similar format as in Table 5.6, and it is observed that in this case low risk of C-section women have C-sections in 23% of cases and for high risk in 71% of cases. My main results for haemorrhage and perineal laceration are confirmed, and C-sections causes both health outcomes only in low-risk women. But now there is no difference between low and high risk women for sepsis and puerperal infections.

Finally I consider to use alternative instrumental variables, defined as: Distance (in Km) to the closest obstetrician-led provider and the difference in distance (in Km) from women to the closest obstetrician-led provider and the distance from women to the next nearest and higher level provider. This second alternative measures the cost in distance to access a higher obstetrician provider than the nearest one. I find that the point estimates for these models are slightly different but the results are not different in terms of confidence intervals.

Overall, my results are robust to changes in specifications. The results for the finding in heterogeneity are also robust. I find that C-sections cause haemorrhage, the most serious maternal complication apart from death, and especially in low C-section risk women.

5.5 Discussion and concluding remarks

I have not found an effect of C-section on maternal mortality. The results suggest that C-sections cause an increase in haemorrhage, sepsis and puerperal infections and a reduction of perineal lacerations. The effects are mainly for women with low-risk C-sections, especially for haemorrhages and perineal lacerations.

Not all complications are equally serious but haemorrhages are considered the worldwide leading cause of maternal death (Say et al., 2014). Therefore I discuss my results in order of importance: death, haemorrhages, sepsis, puerperal infections and perineal lacerations.

Schuitemaker et al. (1997) found that the risk of dying from C-section was seven times greater than with vaginal delivery in The Netherlands. Gonzales et al. (2013) found a correlation between maternal mortality and C-sections in Peru using a different set of health providers. My approach contrasts with this study in the use of a more robust methodology. However my finding of no effect on maternal mortality should be treated with caution. Even though I use a large sample size in this study, this may not be large enough to detect an effect on a very rare outcome. Therefore it could be preferable to use a national Peru sample, rather than from the capital.

Wang et al. (2010), using a matching methodology, report an effect of C-section on haemorrhages in China. I improve the identification using instrumental variables techniques and consider in the sample all women, instead of only low-risk nulliparous women, so my results can be interpreted more broadly.

Johnson and Rehavi (2016) finds that physicians who are themselves mothers do not change their likelihood of haemorrhage by having less C-sections. This suggests that even with obstetricians knowledge, they still suffer the same rate of haemorrhage as those mothers who are not[5]. My findings indicate I should expect that the effect of reducing C-sections should be even more pronounced in physicians themselves, so my results contrast markedly with Johnson and Rehavi.

Currie and MacLeod (2017) combines bleeding, a proxy of haemorrhage, with fever and seizures at delivery in a composite variable as a bad maternal health outcome. However as their focus is not directly on the effect of C-sections, rather than physicians' skills, they found that an increase in skills reduces this bad outcome in lower risk women and hypothesises that could be due to fewer C-sections. I use their methodology to estimate low and high risk women and my results go in the same direction with the difference that it aims to attribute directly that C-sections cause haemorrhage in low risk women.

This study is one of the first that includes sepsis separated from puerperal infections as clearly different health outcomes, and to do this I take advantage of the highly detailed dataset provided with all ICD codes. Until recently infections were reported together with sepsis (Khan et al., 2006). Sepsis is life threatening and potentially can require treatment in intensive care units and high use of antibiotics that can affect the mother and the baby. In addition this is associated with other complications, such that in the cross tabulation of complications, not shown here, women with sepsis have at least one additional complication in a third of the cases, including infections.

I find that C-sections increases sepsis less than it increases infections, but as I state, sepsis is more serious. Regarding infections I find results in the same direction as in Johnson and Rehavi (2016).

I include perineal laceration for comparison reasons. I have not found literature that links this complication to maternal death, at least not to the extent of the other health outcomes. Previous

[5]Johnson and Rehavi (2016) use physicians, or partners of physicians, as they do not focus directly on the effect of C-sections on health outcomes but rather the effect to being a physician on C-sections and being a physician on health outcomes, then mothers can benefit by having lower C-sections due to better information, but can also improve health outcomes for the same reason.

medical literature does not find a correlation of C-sections and perineal laceration (Villar et al., 2006), but the economic literature finds that C-sections reduce perineal lacerations (Card et al., 2019). I find that the effect of C-sections in reducing perineal lacerations is small and mainly for low-risk women.

Most of the recent economic literature does not include haemorrhage, sepsis and infections in their set of maternal health outcomes. I recommend that future studies should include these health outcomes or other equivalent serious maternal complications. This is important because the benefit of a C-section could be overstated if only less serious health outcomes are examined. This seems to be the case in Card et al. (2019), where it was reported that C-sections reduce perineal laceration and length of stay, and improve child health outcomes which led them to recommend relocating deliveries to high C-section performers. But given that other more serious health outcomes was not considered the estimation of the potential economic benefits from this policy are likely to be overstated[6].

Similarly, Amaral Garcia et al. (2019) find that internet diffusion increased C-sections but this had no effect on maternal or child health outcomes, but their maternal health does not include haemorrhage.

More generally, my results are relevant to countries that share the same C-section rate such as, in Asia: Sri Lanka (31%) and Georgia (37%), in the Latin American and the Caribbean: Belize (29%), Cuba (29%), El Salvador (30%), Nicaragua (30%) and Panama (28%), in Oceania: Australia (32%) and New Zealand (33%), in Europe: Bulgaria (33%), Hungary (33%), Poland (30%), Romania (36%), Albania (30%), Malta (33%), Portugal (36%), Germany (30%) and Switzerland (32%) (Betrán et al., 2016b) and, also for examining the public sector, England (30%) (NHS Digital, 2015).

Particularly, in Peru, my results should be interpreted in the context of public hospitals in Lima which have a rate of C-sections of around 33%. It is possible that the effects of C-sections differ in Peruvian provinces that had generally lower C-section rates, or where there are higher rates of C-section such as in the Peruvian Health Social Security System, ESSALUD, and for women treated in private providers or financed with private insurance.

There is evidence that in some African countries with low C-section rates there is an association between elective C-section and fewer stillbirths and neonatal deaths (Shah et al., 2009). I cannot rule out a beneficial effect of C-section on poorer parts of Peru where there is less easy access to C-sections.

The policy relevance of this study is that it suggests it is possible to improve women's health outcomes by reducing C-sections. C-sections are more costly than vaginal deliveries and there are also potential financial savings from not treating complication of C-sections, which may lead to greater use of intensive care units, longer length of stay and greater use of antibiotics.

For illustration I present a non-exhaustive back-of-the envelope analysis. Using information in the analytical sample, the length of stay for a women with haemorrhage after a C-section is about 4.6 days, for sepsis 6.7 days and for puerperal infections 5 days. Each day costs 16.82 Soles (Peruvian currency), and the difference between the payment for C-section and vaginal deliveries is 180.77 Soles. Then using the parameters estimated and the 2015 purchasing power parity conversion factor (World Bank, 2015), the public insurer incurred about 1.1 million US dollars due to the differential price between C-sections and vaginal deliveries and incurred an

[6] Card et al. (2019) estimates a net economic benefit of nearly 8 million USD Dollars for every 1000 child deliveries reallocated to high C-section performer hospitals.

additional cost of 2.1 million US dollars for hospitalisation due to complications of C-sections.

This does not include the cost of medication and possible use of blood transfusions or an Intensive Care Unit.

Although in this study I am not able to assess the effect of C-sections on neonatal health outcomes my results suggest that policy to influence the C-section rate should consider the effects of C-sections on mothers as well as on children.

Appendix A: Additional tables and figures

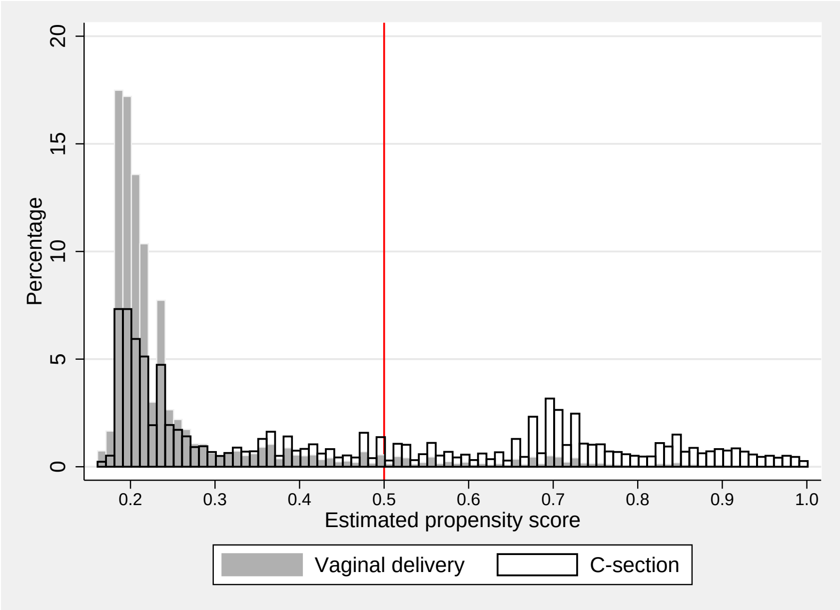

Figure (A5.1) Histograms of predicted risk of C-sections ($\hat{h_i}$) by type of delivery. Fitted by logistic regression using additional covariates of the delivery period

Table (A5.1) Descriptive statistics for women's characteristics from the pre-delivery period

	All sample	C-sections	Vaginal delivery	Diff means
Age 1 (< 21 years)	0.259 (0.438)	0.225 (0.418)	0.276 (0.447)	−0.051***
Age 2 (21 - 25 years)	0.276 (0.447)	0.261 (0.439)	0.284 (0.451)	−0.023***
Age 3 (26 - 30 years)	0.214 (0.410)	0.222 (0.415)	0.210 (0.407)	0.012***
Age 4 (31 - 35 years)	0.148 (0.355)	0.165 (0.371)	0.140 (0.346)	0.025***
Age 5 (> 35 years)	0.103 (0.304)	0.127 (0.333)	0.091 (0.287)	0.036***
Delivery before	0.068 (0.253)	0.067 (0.251)	0.069 (0.253)	−0.002
Length of stay (in days) before delivery	0.352 (1.747)	0.575 (2.324)	0.243 (1.364)	0.332***
Gestational hypertension	0.037 (0.188)	0.053 (0.224)	0.029 (0.168)	0.024***
Pre-eclampsia	0.055 (0.229)	0.084 (0.277)	0.041 (0.199)	0.043***
Haemorrhage in early pregnancy	0.021 (0.143)	0.028 (0.165)	0.017 (0.130)	0.011***
Diabetes mellitus in pregnancy	0.016 (0.126)	0.025 (0.157)	0.012 (0.108)	0.013***
Maternal care for other conditions	0.034 (0.182)	0.045 (0.207)	0.029 (0.167)	0.016***
Multiple gestation	0.006 (0.079)	0.016 (0.125)	0.002 (0.039)	0.014***
Known or suspected malpresentation of fetus	0.039 (0.193)	0.067 (0.251)	0.025 (0.156)	0.043***
Known or suspected disproportion	0.041 (0.197)	0.067 (0.250)	0.027 (0.164)	0.040***
Known or suspected abnormality of pelvic organs	0.109 (0.312)	0.252 (0.434)	0.039 (0.193)	0.213***
Known or suspected fetal abnormality and damage	0.005 (0.068)	0.008 (0.090)	0.003 (0.054)	0.005***
Known or suspected fetal problems	0.051 (0.219)	0.070 (0.256)	0.041 (0.199)	0.029***
Polyhidrammios	0.009 (0.094)	0.015 (0.120)	0.006 (0.078)	0.009***
Disorders of amniotic fluid and membranes	0.016 (0.124)	0.021 (0.143)	0.013 (0.113)	0.008***
Premature rupture of membranes	0.014 (0.116)	0.017 (0.129)	0.012 (0.109)	0.005***
Placental disorders	0.024 (0.152)	0.030 (0.171)	0.020 (0.141)	0.010***
Placenta praevia	0.009 (0.097)	0.016 (0.125)	0.006 (0.079)	0.010***
False labour	0.073 (0.260)	0.095 (0.293)	0.062 (0.242)	0.032***
Prolonged pregnancy	0.009 (0.096)	0.011 (0.105)	0.008 (0.091)	0.003***
Infectious and parasitic diseases classifiable elsewhere	0.014 (0.116)	0.015 (0.120)	0.013 (0.115)	0.001***
Observations	287,460	94,865	192,595	287,460

Note: Means with standard deviations in parenthesis. Difference in means test * p<0.1, ** p<0.05, *** p<0.01.

Table (A5.2) Descriptive statistics for women's co-morbidities recorded at the time of delivery

	All sample	C-sections	Vaginal delivery	Diff means
Gestational hypertension	0.019	0.029	0.015	0.014***
	(0.138)	(0.166)	(0.121)	
Pre-eclampsia	0.073	0.139	0.041	0.099***
	(0.260)	(0.346)	(0.197)	
Eclampsia	0.001	0.002	0.000	0.002***
	(0.027)	(0.043)	(0.013)	
Infections of genitourinary tract in pregnancy	0.057	0.073	0.049	0.024***
	(0.231)	(0.260)	(0.215)	
Diabetes mellitus in pregnancy	0.004	0.008	0.002	0.006***
	(0.059)	(0.087)	(0.040)	
Maternal care for other conditions	0.007	0.009	0.006	0.003***
	(0.081)	(0.094)	(0.074)	
Multiple gestation	0.005	0.014	0.001	0.013***
	(0.070)	(0.117)	(0.024)	
Complication specific to multiple gestation	0.000	0.001	0.000	0.000***
	(0.016)	(0.023)	(0.011)	
Known or suspected fetal abnormality and damage	0.001	0.003	0.000	0.003***
	(0.037)	(0.058)	(0.019)	
Known or suspected fetal problems	0.025	0.038	0.019	0.019***
	(0.157)	(0.191)	(0.137)	
False labour	0.002	0.004	0.002	0.002***
	(0.047)	(0.061)	(0.039)	
Preterm labour and delivery	0.016	0.026	0.011	0.016***
	(0.124)	(0.160)	(0.102)	
Failed induction of labour	0.003	0.007	0.000	0.007***
	(0.052)	(0.086)	(0.018)	
Abnormalities of forces of labour	0.016	0.014	0.017	−0.003***
	(0.125)	(0.117)	(0.128)	
Long labour	0.012	0.031	0.002	0.029***
	(0.107)	(0.173)	(0.046)	
Observations	287460	94865	192595	287460

Note: Means with standard deviations in parenthesis. Difference in means test * p<0.1, ** p<0.05, *** p<0.01.

Table (A5.3) Full sample logistic regression of women's risk of C-sections

	(1) C-sections β/(SE)	Marg. effect
Age 1 (< 21 years)	−0.149***	−0.026***
	(0.012)	
Age 2 (21 - 25 years)	−0.068***	−0.012***
	(0.012)	
Age 3 (26 - 30 years)	Ref.	Ref.
Age 4 (31 - 35 years)	0.050***	0.009***
	(0.014)	
Age 5 (> 35 years)	0.151***	0.028***
	(0.016)	
Delivery before	−0.169***	−0.030***
	(0.017)	
Length of stay (in days) before delivery	0.066***	0.012***
	(0.003)	
Co-morbidities of the pregnancy period		
Gestational hypertension	0.170***	0.030***
	(0.023)	
Pre-eclampsia	0.251***	0.045***
	(0.019)	
Haemorrhage in early pregnancy	0.043	0.008
	(0.032)	
Diabetes mellitus in pregnancy	0.185***	0.033***
	(0.035)	
Maternal care for other conditions	0.094***	0.017***
	(0.025)	
Multiple gestation	1.140***	0.203***
	(0.079)	
Known or suspected malpresentation of fetus	0.933***	0.167***
	(0.023)	
Known or suspected disproportion	0.871***	0.156***
	(0.022)	
Known or suspected abnormality of pelvic organs	2.138***	0.382***
	(0.015)	
Known or suspected fetal abnormality and damage	0.322***	0.057***
	(0.071)	
Known or suspected fetal problems	0.225***	0.040***
	(0.020)	
Polyhidrammios	0.489***	0.087***
	(0.047)	
Disorders of amniotic fluid and membranes	0.192***	0.034***
	(0.036)	
Premature rupture of membranes	0.109***	0.019***
	(0.040)	
Placental disorders	0.173***	0.031***
	(0.030)	
Placenta praevia	0.586***	0.105***
	(0.045)	
False labour	0.191***	0.034***
	(0.018)	
Prolonged pregnancy	0.297***	0.053***
	(0.046)	
Infectious and parasitic diseases classifiable elsewhere	0.065*	0.012*
	(0.037)	
Co-morbidities at the time of delivery		
Gestational hypertension	0.692***	0.123***
	(0.030)	
Pre-eclampsia	1.402***	0.250***
	(0.016)	
Eclampsia	2.657***	0.474***
	(0.194)	
Infections of genitourinary tract in pregnancy	0.287***	0.051***
	(0.018)	
Diabetes mellitus in pregnancy	1.012***	0.181***
	(0.075)	
Maternal care for other conditions	0.349***	0.062***
	(0.048)	
Multiple gestation	2.428***	0.433***
	(0.098)	
Complication specific to multiple gestation	1.302***	0.232***
	(0.289)	
Known or suspected fetal abnormality and damage	2.253***	0.402***
	(0.131)	
Known or suspected fetal problems	0.735***	0.131***
	(0.025)	
False labour	0.796***	0.142***
	(0.092)	
Preterm labour and delivery	0.861***	0.154***
	(0.031)	
Failed induction of labour	3.540***	0.632***
	(0.135)	
Abnormalities of forces of labour	0.011	0.002
	(0.033)	
Long labour	3.012***	0.538***
	(0.051)	
Constant	−1.332***	
	(0.010)	
Observations	317305	
Pseudo R^2	0.151	

Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parentheses.

Table (A5.4) Sensitivity using an increase number of covariates to predict women's C-section risk, heterogeneity on the effect of C-section on maternal health outcomes

	(1)	(2)	(3)
		C-Section risk	
	Average	Low	High
Maternal death	0.00001	−0.00003	−0.00005
	(0.0001)	(0.0001)	(0.0002)
Haemorrhage	0.013**	0.015**	0.003
	(0.006)	(0.006)	(0.006)
Sepsis	0.010***	0.010***	0.010***
	(0.003)	(0.003)	(0.003)
Puerperal infection	0.044***	0.044***	0.041***
	(0.015)	(0.002)	(0.012)
Perineal laceration	−0.017**	−0.013**	−0.032
	(0.009)	(0.006)	(0.021)
Deliveries	287,460	192,595	94,865
C-section rate	33%	23.42%	71.14%

Note: * p<0.1, ** p<0.05, *** p<0.01. First the logistic regression of women's C-section risk is estimated by logistic regression (reported in Table A5.3) which includes an additional set of patients co-morbidities, second, low and high risk is defined if the predicted propensity of C-sections is greater or lower than 0.5, and third the instrumented biprobit estimation is regressed with dummy interaction to capture C-section heterogeneity according to women's C-section risk.

Chapter 6

Conclusion

This thesis presents four empirical studies that explore maternity care in Peru. In this concluding chapter I briefly summarise the key findings and suggestions for future research.

6.1 Summary of key findings

Examining the demand side in Chapter 2, I find that women forego continuity of care in midwife-led maternity units, classified as lower structural quality providers, preferring obstetrician-led providers regarded as higher structural quality in terms of staffing and equipment, and being willing to travel further.

The cost per delivery in obstetrician-led maternity units are higher than in midwife-led maternity units, so then the public funds used in maternity units are greater than if women were sorted into maternity units by health risk. In Lima, policy makers responded by opening three new midwife-led maternity units in three micro-networks, reducing travel distance. It was therefore hoped that women in each micro-network would be more likely to choose midwife-led units, thereby reducing C-section rates. In micro-network 1 the new midwife-led maternity unit was opened in 2012 near to a pre-existing midwife-led maternity unit and also near to an obstetrician-led maternity unit. In micro-network 2 the new midwife-led maternity unit was opened in 2013 near to a midwife-led unit but far away from an obstetrician-led maternity unit. These contrast with micro-network 3, where the new midwife-led maternity unit was opened in 2015 far from any other midwife-led maternity unit and near to an obstetrician-led maternity unit.

In Chapter 3 I find that the effects of the policy are related to the distance from the new midwife-led maternity unit to the existing obstetrician-led maternity unit, and to midwife-led maternity units. The closer to an obstetrician-led provider the greater the effects and the closer to a midwife-led maternity unit the lesser the benefits.

Ordered from the higher to the lower effects of the policy, Chapter 3 shows that the policy has the biggest effect on micro-network 3 in increasing consumer surplus, reducing women's use of obstetrician providers, reducing C-sections, and a weak effect on increasing midwife-led continuity of care and reducing perineal laceration. There is a medium effect on micro-network 1: increasing consumer surplus, reducing women's use of obstetrician providers and increasing midwife-led continuity of care, and least effect on micro-network 2 with increasing consumer surplus and a weak effect on increasing midwife-led continuity of care. I also find that the effects on consumer surplus are modest compared with the investment required to finance the opening of new midwife-led maternity units.

Chapter 4 shows that the higher is capacity variable (defined as the ratio of obstetricians/child deliveries) in a maternity unit, the higher the C-section rates. As capacity also increases the use of easy-to-upcode co-morbidities, I argue that this suggests that obstetricians perform C-sections upon convenience by upcoding co-morbidities for the women and, in healthy women, co-morbidities for the babies justifying the decision to perform unnecessary C-sections.

The overall effect of the capacity variable on women's health outcomes are mixed. Taking into account only the serious life-threatening complications, capacity reduces haemorrhages, but increases puerperal infections, and has no effect on sepsis or maternal mortality.

Chapter 5 shows that C-sections increases haemorrhage, sepsis and puerperal infections, with no effect on maternal mortality. The effect of C-sections on haemorrhage, one of the main causes of maternal mortality worldwide was greater for healthier women who would have been less likely to get a C-section.

My results in Chapter 2 are generalizable to big cities where women have a choice of hospitals with different structural qualities geographically separated.

My findings in Chapter 3 are generalizable to countries where there are policy shift in favour of opening midwife-led maternity units.

My findings in Chapter 4 are generalizable to maternity units with surgical capabilities in countries with soaring C-section rates, regionally this occurs worldwide with the exception of Africa and Sub-Saharan Africa where the C-sections are comparatively low.

My finding in Chapter 5 are generalizable to countries that share the same C-section rate such as, in Asia: Sri Lanka (31%) and Georgia (37%), in the Latin American and the Caribbean: Belize (29%), Cuba (29%), El Salvador (30%), Nicaragua (30%) and Panama (28%), in Oceania: Australia (32%) and New Zealand (33%), in Europe: Bulgaria (33%), Hungary (33%), Poland (30%), Romania (36%), Albania (30%), Malta (33%), Portugal (36%), Germany (30%) and Switzerland (32%) (Betrán et al., 2016b) and, also for examining the public sector, England (30%) (NHS Digital, 2015).

6.2 Additional insights from between-chapters analysis

Findings in Chapters 2 and 3 together suggest that, in big cities like Lima, women are increasingly likely to use obstetrician-led providers and that opening new midwife-led maternity units are ineffective in affecting this trend except when opened near an obstetrician-led unit.

These findings suggest that women are increasingly willing to travel longer distances, and as shown in Chapter 2, this seems to be due to changes in preferences rather than changes in the composition of women's co-morbidities. Thus the potential benefits of new midwife-led maternity units in reducing use of obstetrician-led units and reducing C-sections are likely to decline.

Figure 6.1 plots the trend in choices of child delivery for midwife-led maternity units and for tertiary obstetrician-led providers. The former decreases while the latter increases over time. The average distance travelled for child delivery has increased over time.

At the start of the period about 22% of women chose midwife-led maternity units and about 55% national hospitals, which are tertiary obstetrician-led providers. The rest (about 23%), which are not plotted, chose secondary level obstetrician-led providers. Overall, at the start of the period, women travelled about 4.5km for child delivery. At the end of the period about 15%

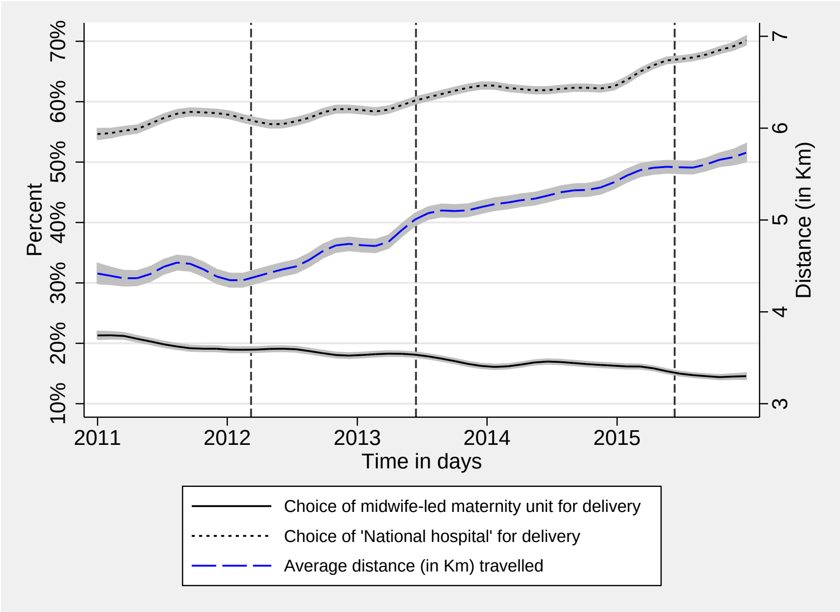

Figure (6.1) Trends in women's choice of midwife-led providers and obstetrician-led tertiary 'national hospitals' for child delivery

Note: The vertical dashed lines signals the implementation of three midwife-led maternity units, in order: the first opened in March 2012, the second in June 2013 and the third in June 2015. There are two groups of obstetrician-led providers: secondary level providers (not plotted) and tertiary level providers. The average distance is estimated using choices of all women regardless their choice of type of provider

chose midiwfe-led maternity units and 70% national hospitals. The average distance travelled rose to slightly less than 6km.

In this context, the policy of opening new midwife-led maternity units studied in Chapter 3, represented with vertical dashed lines, has a barely perceptible impact. This reinforces the policy recommendation to only open new midwife-led maternity units in places where their potential has been proven effective. This is in geographical areas with high C-section rates due to direct access to obstetrician-led providers, such as with micro-network 3 identified in Chapter 3.

Chapters 4 and 5 together allow exploration of the direct and indirect effects of the capacity variable (the ratio of obstetricians/child deliveries) on health outcomes. The 'direct' effect is the change in outcomes for a given procedure due to greater capacity. 'Indirect' is the change in the mix of procedure due to greater capacity. Greater capacity plausibly improves outcomes for a given treatment but affects the mix of treatment.

The capacity variable directly affects health outcomes and C-sections. Since as shown in Chapter 5 having a C-section worsens health outcomes, the overall effect of capacity on health outcomes depends of the direct effect of capacity on health outcomes plus the indirect effect through performing C-sections. The overall effects are reported in Chapter 4.

Let $y_c(k)$, $y_v(k)$ be the probability of an outcome (say haemorrhage) for women having C-section or vaginal delivery, respectively, and k be the obstetrician/delivery ratio. The risk of haemorrhage is

$$y(k) = \theta(k)y_c(k) + [1 - \theta(k)]y_v(k) \tag{6.1}$$

where $\theta(k)$ is the probability of a C-section.

Then the overall effect of capacity (k) on haemorrhage risk is:

$$\frac{dy(k)}{dk} = \frac{d\theta(k)}{dk}[y_c(k) - y_v(k)] + \theta(k)\frac{dy_c(k)}{dk} + [1 - \theta(k)]\frac{dy_v}{dk} \tag{6.2}$$

In Chapter 5 I show $y_c(k) > y_v(k)$ for haemorrhage. In chapter 4 I show $\frac{d\theta(k)}{dk} > 0$ so $\frac{d\theta}{dk}[y_c(k) - y_v(k)] > 0$.

In Chapter 4 I show $\frac{dy(k)}{dk} < 0$. I have not tested for the sign of dy_c/dk and dy_v/dk but the fact that $dy/dk < 0$ implies that $\theta\frac{dy_c}{dk} + (1-\theta)\frac{dy_v}{dk} < 0$ so that one of (or both) y_c or y_v is reduced by k.

The challenge to identify the effect of capacity on y_c (and on y_v) using the Sunday sample (from Chapter 4) and using the distances instrumental variables (in Chapter 5) is that Chapter 4 relies as identification strategy on the use of providers and obstetricians fixed effect while Chapter 5 relies on instrumental variables using biprobit where the use of providers and obstetricians fixed effects are problematic. In future work I will explore how to overcome this limitation to identify the effect of capacity on y_c (and on y_v).

As C-section increases haemorrhages, sepsis and puerperal infections, and that capacity increases C-sections (Chapter 4), the indirect effect of the ratio of obstetricians/child deliveries is that it worsens these health outcomes.

From the overall effect of the ratio of obstetricians/child deliveries on health outcomes, as reported in Chapter 4, the following is deduced: first that the direct effect of the capacity variable reduces haemorrhages and prevails over the increase due to the indirect effect of capacity on health outcomes through the increased rate of C-sections. That is, the capacity variable directly reduces haemorrhages, but indirectly increases haemorrhages through C-section, and the overall effect is that capacity reduces haemorrhages. Second the direct effect of capacity on sepsis is the same as with the indirect effect caused by the capacity through C-sections but with opposite sign. So overall capacity does not have an effect on sepsis, even though C-section increases the risk of sepsis. Arguably obstetricians manage to control potential cases of sepsis that are caused by the increase in C-sections when there are more obstetricians on duty per woman. Third the direct effect of the capacity variable on infections is lower than the indirect effect of capacity on infections through C-sections. Even though obstetricians may try to control infections, the indirect effect prevails. Arguably, obstetricians cannot prevent the rise of infections caused by the increase in C-sections when there are more obstetricians on duty per woman.

The policy relevance of chapter 4 and 5 is that these findings suggest the necessity of regulation, especially for easy-to-use codes such as for foetal stress.

Chapter 2, 4 and 5 together suggest that women value higher structural quality and increasingly choose obstetrician-led providers. Those obstetrician-led providers perform more C-sections due to convenience worsening some health outcomes and improving others. The Seguro Integral de Salud (SIS), the public insurer, is paying more for worsening some women's health outcomes. That is, SIS is paying more for C-sections, due to the differential price between C-sections and vaginal deliveries, and in treating complications of C-sections, which results in a higher length of stay in hospital and increased cost of medication.

6.3 Limitations

There are some limitations in this thesis which are summarised as follows.

First, there are no women's address in the dataset, so that distance was computed by the most used non maternity provider for non-emergency cases.

Second, it is important to account for child health outcomes as well as for maternal health outcomes, and although there are both types of information in the dataset it was not possible to link mothers with babies due to to pseudonymised data.

Third, the dataset only covers Lima and this does not allow to study each research question in rural areas where the access to maternity care are likely limited.

Fourth, the dataset contain deliveries in the public sub-system covered by SIS, this does not allow to study each research question more broadly in ESSALUD, the employment based health insurance, and the private sub-system, where the C-section rate are likely higher.

Fifth, mother's characteristics was constructed using information of health records alone in 2011-2015. There are no records of how many children they have, or previous C-sections, these information was constructed in-sample only if recorded. Women are generally poor to access this health insurance, but there is no socieconomic characteristics recorded such as education or income level, these are important because attitudes to childbirth is influenced by socioeconomic characteristics.

6.4 Suggestions for further research

Although this thesis is the first study that systematically examines the economics of maternity care in Peru, it is still far from having a complete picture of all its characteristics. Therefore I suggest further research using the same dataset and using complementary information.

First, as I have noted the research was limited by the impossibility of examining child health outcomes due to pseudonymised data. Therefore I will request from the data providers, the pseudonymised link between mothers and babies to include child health outcomes in the analysis. This is important because policy makers should design policies based on their impacts on maternal and child health outcomes.

Second, regarding the maternal health outcomes evaluated in the thesis I recommend using the larger national dataset to study the effect on rare health outcomes such as maternal death.

Third, to investigate whether there are differences in health outcomes across health sub-systems. This is because in the Peruvian context, as explained in the introductory chapter, there are three main sub-systems: first, the public sub-system studied in this thesis, second, ESSALUD a closed sub-system based in income contribution from and for workers, and third the private sub-system.

Obstetricians can work in more than one sub-system at the same time. These configurations offer a unique opportunity to understand if obstetricians behave differently according to different institutional arrangements in each sub-system.

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Ethical approval statement

This project used only secondary administrative data. All patient-level data supplied by the Health Ministry of Peru were pseudonymised, and no personal information was included. Ethical approval was not required as this study does not involve patients directly, all reported results are at an aggregate level, and patients are not potentially identifiable from the data.

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